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A Study of Interacanding and Companion Galaxies: Implications for Cosmology

Kristen Petrillo
Pomona College

A Study of Interacting and Companion Galaxies: Implications for Cosmology

by

Kristen Petrillo

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Table of Contents

Chapter 1: Introduction

1.1 Interacting Galaxies

Observations of the brightness and the mass of galaxies give a general luminosity/mass function that, due to the differences in intrinsic luminosity in galaxies, covers a wide range. A luminosity function shows the number of galaxies at a specific luminosity. Since the number of galaxies at any specific luminosity will obviously depend on the total number of galaxies in question, luminosity functions must be normalized in order to compare them. Mass and luminosity are closely related, so it is often called a luminosity/mass function. Modern theories of galaxy formation predict an order to the build-up of galaxies. First the non-luminous but comparatively massive dark-matter halos form, then the baryonic sub-components form the parts of the galaxy that are optically visible. It is by these baryonic sub-components that galaxies are currently categorized. The Hubble Type Classification scheme breaks galaxies into the spiral, elliptical, and irregular galaxy classifications by their baryonic components: stars,

gas, and dust. The dark-matter halos also consist of embedded gas and dust, but these baryons are not visible to us because there is nothing producing light nearby to illuminate them. Researchers have used this hierarchical galaxy formation model to create simulations to discover the physical properties behind galaxy formation. Figure 1 shows the general luminosity function determined by Cole et al. (2001) from their observational

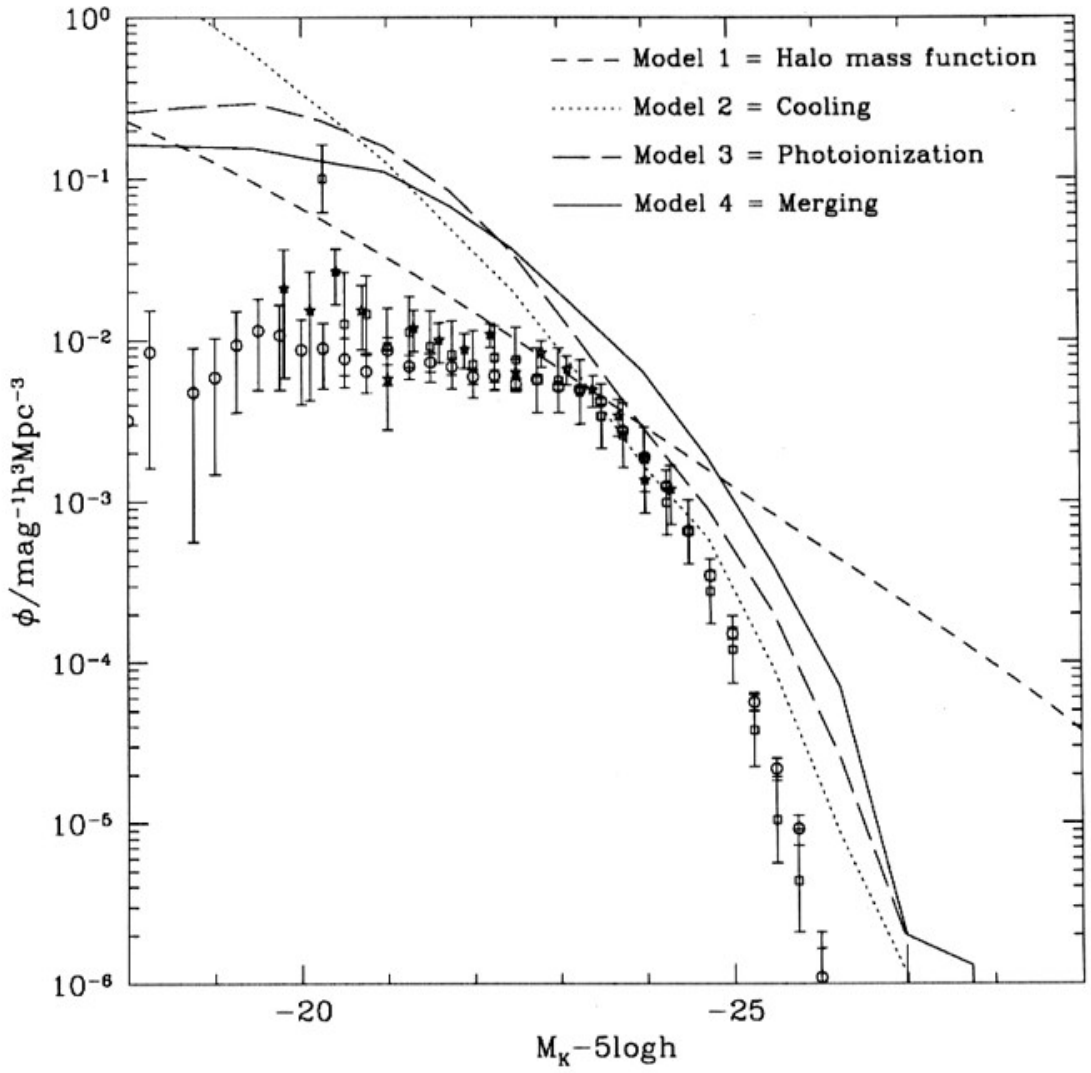

Figure 1: The number density of galaxies in the local universe vs. K-band magnitude. The straight line is the cold dark matter model. In order to account for the discrepancies everywhere except at L* many theorists have speculated the existence of pure dark matter galaxies, or Gravitating Non-Luminous (GNL) galaxies. (Benson, et al. 2003)

data, along with two curves produced from simulations based on a modified version of the hierarchical theory of how galaxies form and evolve as shown in Benson et al. (2003). Simulations and computer models begin with hypothetical situations and let physical properties do their work over some period of time. In Figure 1 you can see a luminosity function derived from the halo mass theory and another adding in the effects of cosmological reionization. Both of these theories predict more galaxies than are observed at almost all luminosities. This idea of galaxies that should exist that we do not see is generally called the "missing satellite problem." This nomenclature presumes that the theory is correct and that observers are obliged to find out why they missed these objects.

Various theories have been proposed attempting to solve the so-called "missing satellites problem." Some have suggested that the satellites are there, but that they are impossible to see because none of the matter in the galaxy is luminous. That is, the galaxy exists, but is entirely made of a dark matter halo that we cannot detect with telescopes that observe photons. The theory is that either the baryonic sub-components never formed in these galaxies, or they were stripped away somehow. In order to check for these theoretical "dark companions," a variety of tests have been performed. In a paper by Madore, Nelson, and Petrillo (2008), the authors inspected galaxies that appeared gravitationally perturbed in optical images, and checked for visible companions. The idea behind this test was that a dark matter halo interacts gravitationally with another galaxy much in the same way two galaxies with baryonic components would interact. Any dark companions would show themselves through a gravitational distortion of the primary "parent" galaxy. By searching through galaxies whose morphologies can only

be produced by gravitational interactions, and then looking to see if there is a visible companion, we can search for one of two options. Either the test will show that many gravitationally distorted galaxies do not have visible companions, so the distortion must have occurred due to a dark companion, or the test will prove that most galaxies that have obviously been gravitationally interacted with have a visible companion plausibly responsible for the interaction. Out of 104 galaxies known to have been caused by gravitational interactions (ring galaxies, described below), Madore, Nelson, and Petrillo found that none had compelling evidence for being an optically isolated galaxy. That is, plausible optical companions were found near every ring galaxy observed (within 3 ring radii from the center of the galaxy). Possible further research to do beyond the scope of this paper is to choose a control sample of normal, unperturbed galaxies, and search for plausible companions within the same 3 ring radius used to search for ring companions. This test would prove that this is not just a case of all galaxies having a plausible companion within this radius.

After searching for dark companions that might possibly account for the "missing satellites" that the simulations predicted, it appears that the problem is not one of missing satellites as was previously suggested, but instead that there is an excess of companions produced from the simulation. In fact, orders of magnitude more galaxies were expected in the universe than were found optically (Figure 1). Our observations suggest that the discrepancy between the observations and simulations are real and that this is not simply a case of observational incompleteness. The theory behind the simulations must not accurately describe the physical properties that go into forming galaxies, and excess satellites are produced in the simulation data. Instead of continuing to look for missing

satellites, I suggest that we now focus on the "Excess Companions Problem," which means trying to find new theories behind galaxy formation that would produce fewer companions at all magnitudes.

1.2 The Cosmological Evolution Survey (COSMOS)

The Cosmological Evolution Survey (COSMOS) is a project that began collecting data in 1994. The survey covers 2 square degrees on the sky, and over 2 million galaxies were detected. It is a fairly deep survey ($0.5 < z < 3$), which covers from when the universe was 2.2 Gyr old (11.1 billion years ago) to when the universe was 8.4 Gyr old (4.8 billion years ago). Sources closer to earth than $z = 0.5$ are also included in the survey, but they mainly appear as obstructions to the background galaxies. The COSMOS survey includes well-imaged galaxies from 47.5% of the age of the universe. Since it is such a large survey, with such a massive amount of galaxies detected, I used a representative sample in order to get data about the COSMOS field. This was necessary because I wanted to see the distribution of all of the galaxies in the field. I chose a region near the center of the 2 square degree field with a radius of 350 arcseconds, about 5% of the entire COSMOS field. This region contained 6128 sources in it, and I assumed that the data set from those galaxies would be representative for the entire COSMOS field. The average redshift of a galaxy in this representative area of the COSMOS field is $z = 1.1$, which corresponds to 5.5 Gyr after the beginning of the universe (7.7 billion years ago). In order to calculate distances and ages from redshift, I used the cosmological parameters $H_0 = 75$ km/s/Mpc, $\text{Omega}_{\text{matter}} = 0.25$, and $\text{Omega}_{\text{vacuum}} = 0.75$.

Imaging for this project has been done by the Hubble Telescope (optical), the Spitzer Space Telescope (infrared), The Galaxy Evolution Explorer (GALEX)

(ultraviolet), The Chandra X-Ray Observatory (x-ray), the Subaru Telescope National Astronomical Observatory (optical-infrared), The Very Large Array (VLA) (radio), the ESO Very Large Telescope (VLT) (near ultraviolet-infrared), and several others.

COSMOS is a unique project because it is unusual to have most of the best telescopes in the world focus on the same area of space. Individual telescopes usually focus on detecting a small range of light wavelengths. Astronomical sources that we detect on earth (or from the atmosphere) either produce electromagnetic radiation or absorb and then reemit radiation from other sources. Those that produce light generate it at a specific range of wavelengths, whereas the light that is absorbed and then reemitted loses some of its energy. Since the energy of a light wave is inversely proportional to its wavelength, on a spectrum measuring amount of light detected vs. wavelength, it would be reasonable to see peaks in different areas of the spectrum depending on whether the light had been absorbed and reemitted or was directly from the source. The absorption and reemission takes energy from the light wave, meaning it will peak at a lower wavelength than it would have had it not been absorbed. For this reason, getting information about an object from multiple telescopes and multiple wavelengths is crucial in fully understanding the object.

The purpose of COSMOS is to probe the universe to both find evidence of the way galaxies form and evolve and to examine large scale structure in the universe. Both of these are relatively difficult things to explore. Large-scale structure (where galaxies tend to clump in the universe) must involve a wide field of view, simply because any grouping of galaxies will have to occur over a large area of space. Finding evidence of forming and evolving galaxies at a high redshift is also important because galaxies today

may have formed and evolved differently than they did in the past.

Later in this paper, a catalog of a specific type of galaxies from the COSMOS data will be presented. I searched through the images that the Hubble Space Telescope took with the ACS f814w filter (*I*-band) and found every possible ring galaxy in the 2 square degrees of sky that COSMOS observed.

1.3 Ring Galaxies

Ring galaxies are disk galaxies with a fairly peculiar morphology. They tend to have some kind of nucleus (though not always) and are surrounded by a ring of material. Models have been proposed to explain the physical properties at work behind the origin of these strange morphologies. The model that has now been widely accepted is a collisional model, where a small companion collides with a disk galaxy in a "head on" orientation. That is, if the disk were tilted so that you could only see an edge, the companion would come from above or below and pass through the middle of the disk. The smaller collider would then continue past the disk. The galaxies do not merge, and the stars themselves do not collide, but the parent disk galaxy is altered by the gravitational interaction with its companion. A density wave forms at the contact point (in the center/near center of the disk galaxy), and spreads outward through the disk. The gas in the disk is compressed together as the wave passes through it, and compressed gas is the beginning of stars. Not only is a ring structure formed through simulations just from material being forced away from the center (see ring simulations Figure 2, Figure 3), but the condensed gas begins to form stars, and the ring around the contact point becomes even brighter.

In ring galaxy formation, the collider does not become gravitationally bound to

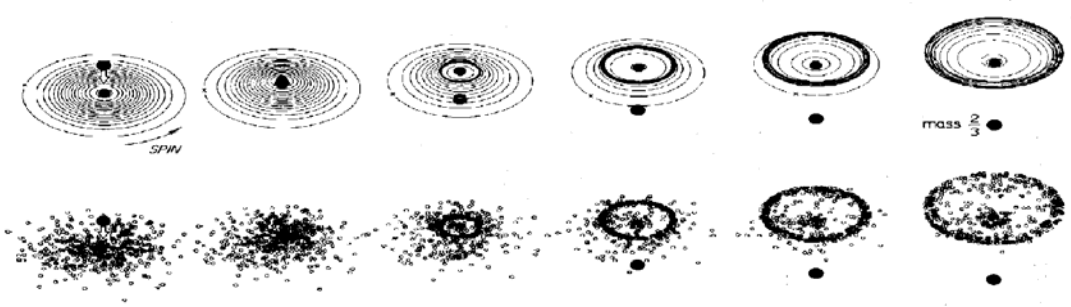

Figure 2: Results of an axial penetration of a Gaussian disk by a point-like mass 2/3 the mass of the primary galaxy. Adapted from Lynds and Toomre (1976)

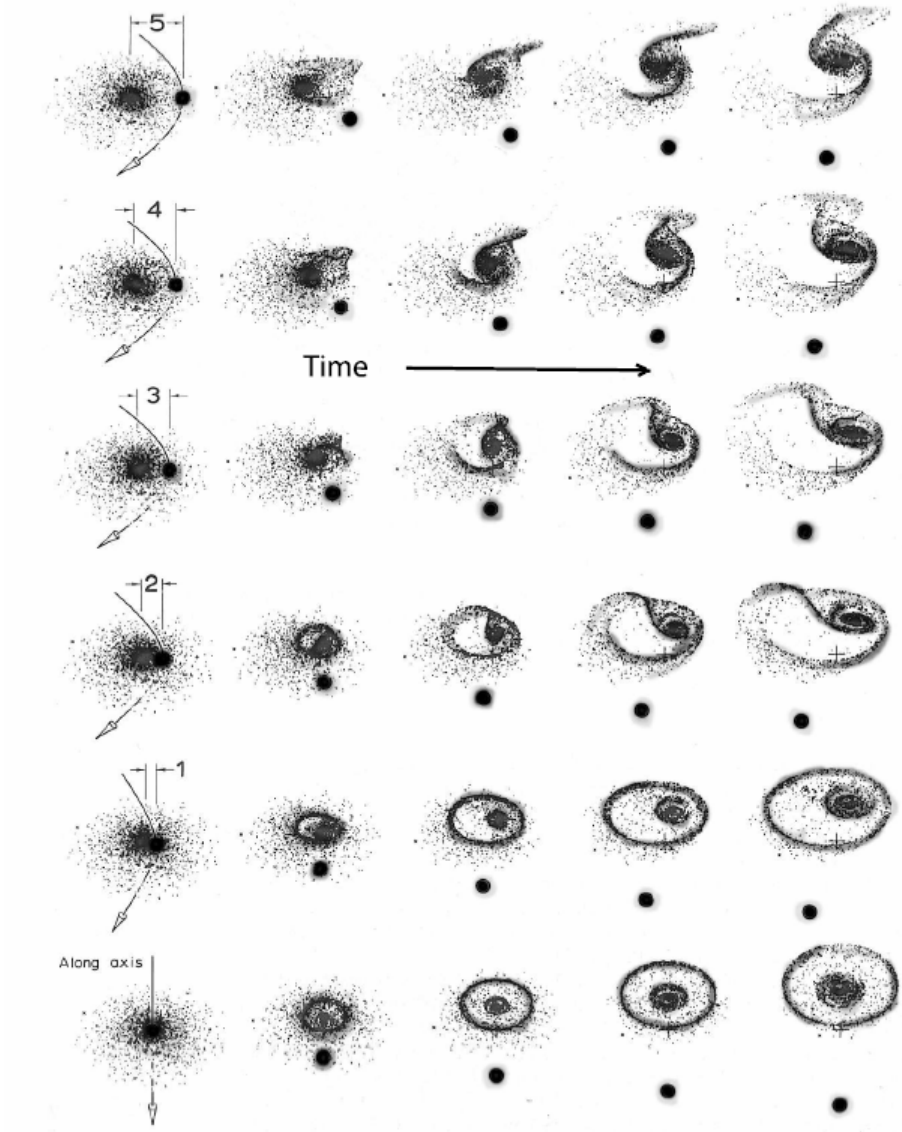

Figure 3: 6 vertical collisions of a smaller, point-like galaxy with a disk of 2000 test particles. Adapted from Toomre (1978).

the disk and the events are short-lived. Ring galaxies are physically unstable, and do not last long (given an astronomical time scale). The probability of a smaller galaxy running head-on into a disk is small. The morphological change created by the interaction is not permanent, and we cannot see rings at all from edge on. Given these facts, it is not surprising that ring galaxies are fairly rare objects to find in the sky. To create their Catalog of Southern Peculiar Galaxies and Associations (1987), Arp and Madore examined approximately 100,000 galaxies, and only classified 552 as Category 6 (ring) galaxies. Since the Arp-Madore Catalog was formed in 1987, a magnitude-limited sample was impossible to create. However, the photographic plates used to create this catalog were part of a uniform survey of the sky covering the southern hemisphere south of declination -20 deg. All galaxies larger than one arcminute and more than 20 deg above the Galactic plane were clearly resolved, making it a complete survey of nearby galaxies within that part of the sky. The Arp-Madore Catalog is size-limited, not considering galaxies less than 1 arcminute in diameter. The ring galaxies in the COSMOS sample are not larger than 15 arcseconds, so it is clear that the Arp-Madore Catalog is a much closer sample than the COSMOS sample. The Arp-Madore sample must be a nearby sample, which suggests that 0.55% of all galaxies and 1 in every approximately 200 galaxies is a ring galaxy in the nearby universe.

In order to compile their catalog, Arp and Madore could not use the same sort of source extraction technique that was used to find galaxies in the COSMOS sample. The observation data that they used was kept on photographic plates instead of digitally, so there was no way to make the sample volume limited or magnitude limited, since it was impossible to determine magnitude and redshift from the plates. The method used is as

follows. One author at a time held a lens magnifier to a photographic plate. The lens was held fixed in the y direction, but could move along the x-axis of the plate freely. As the viewer moved his lens across the plate, he called off the total count of galaxies he viewed, and also the total count of peculiar galaxies. The total galaxy count was around 100,000, and only included items that either Madore or Arp decided were galaxies. This count is hard to compare to the COSMOS sample's claim of viewing over 2 million galaxies, because these "galaxies" are determined by a computer using software to see a rise in the number of photons in a specific place. The universe around redshift $z = 1$ is a very messy place, with plenty of gas and dust and background specks of something that Arp and Madore would never have added into their total galaxy count, but that the programming based source extractor would have no reason to not call a galaxy. Also, two pieces of galaxy that are obviously interacting with each other are often called two separate galaxies by source extractors. This is called shredding, and since one part of the galaxy tends to be brighter than the other, instilling magnitude limits should get rid of this extra signal. The Arp-Madore counts are important because, compared to the COSMOS survey counts, it is possible to compare the nearby galaxy survey (the Arp-Madore Catalog) with the larger redshift COSMOS survey. This comparison will give some sort of information about the dynamics of the universe in the past as opposed to the local universe. Further analysis of this sort is found in Chapter 4.

1.4 The Holmberg Effect

Another study that has been run many times on galaxies with companions is determining the position angles of the companions gravitationally associated with the parent galaxy. Eric Holmberg did the first test of this in 1969, although it was a small

note in a larger paper. He found that companion galaxies preferentially located over the poles of edge-on disk galaxies (see Figure 4). Eventually this idea of the companions of

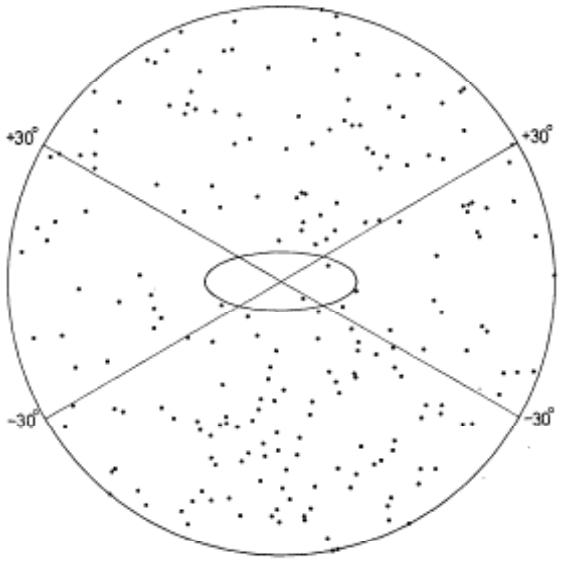

Figure 4: Combined distribution of all companions (background included) discovered around edge-on spirals. The ellipse shows the average size of the primary galaxy, taken from Holmberg (1969).

a galaxy being located mainly above and below the disks of galaxies (instead of extending from the plane of the disk) became known as the Holmberg Effect. The Holmberg Effect can also refer to the color indices of pairs and the relationship between different Hubble type companions (whether it is a spiral, elliptical, or irregular galaxy) and the primary galaxy. In this paper, however, we focus only on the position angle of companions aspect of the Holmberg Effect.

Galaxies can be used to probe the effects of dark matter in the universe. For example, satellites of large galaxies can be used to trace the potential well of the primary galaxy, thus determining where the mass is concentrated in the galaxy. The reason why the Holmberg Effect has never been entirely discounted, even though there have been several papers that have shown that his effect was probably due to small number statistics

and selection effects (Zaritsky, Smith, Frenk, and White (1997), Sales and Lambas (2004), Agustsson and Brainerd (2006)), is that a physical reason for the effect has been proposed. Since companions probe gravity and by extension dark matter halos around parent galaxies, it has been suggested that large-scale structure filaments of matter in the universe are always perpendicular to the disks of spiral galaxies. This has very interesting implications for the way in which galaxies are formed, but if the effect is simply a matter of small number statistics and background contamination, it should be discounted so that we do not assume that galaxies have properties that they do not really have.

In order to test the Holmberg Effect in a manner differently from how others have done it, I use the same primary galaxies that Holmberg used in his original study, but only calculate the position angles of radial velocity confirmed companions. Since Holmberg did not have the same amount of public data available to him, he was unable to determine whether or not the companions he was looking at were actually gravitationally interacting with his primary galaxy or not. I am able to do this using the NASA/IPAC Extragalactic Database (NED), so I can add a new dimension of information to his original study.

Chapter 2: A Modern Analysis of the Holmberg Effect

Holmberg (1969) systematically examined regions around nearby edge-on spiral galaxies and examined the position of any possible companions. He determined the radial separation and the position angle of these companions, and tried to see if any specific position angle or range of position angles were more common. In a single plot he displayed that his sample of apparent companions was anisotropically distributed around edge-on spirals (Figure 4). This apparent preferential distribution of companions above and below the planes of highly inclined spiral galaxy (as opposed to extended beyond the arms) later became known as the "Holmberg Effect."

The difficulty for Holmberg in identifying physical companions was that there was, at that time, no way for him to tell if the galaxies that appeared to surround the primary edge-on spiral were at the same redshift as the primary. There was no information available to separate true (orbiting) companions from background contamination. In order to evaluate whether there was a statistical excess of physical

companions (gravitationally interacting with the primary galaxy) over optical companions (nearby based on our viewpoint, but actually in the background or foreground), Holmberg used nearby comparison areas to estimate the local surface density of background galaxies. These comparison areas were 50 kpc (the same size as the survey area), and were 100 mm east and 100 mm west of the survey area of each edgewise oriented galaxy, so they accounted for local distribution changes and relative clustering of galaxies. Holmberg counted all of the galaxies (up to the same apparent angular size limit) in the survey field and compared it to the amount of galaxies found in the comparison area. His discovery was that companions were more likely to be found at areas above and below the plane of the primary galaxies, near the poles.

Since 1969, there has been a lot of research done on determining the radial velocity positions for large numbers of galaxies in the nearby universe. Considerable progress has been made, and redshifts have now been confirmed for many of the galaxies that Holmberg noted were companion galaxies to his edge-on spirals. The logical thing to do now is to rerun Holmberg's experiment using the available redshift catalogs, and only cataloging the position angles of the galaxies that are confirmed radial velocity companions of the primary galaxies. Since several studies have expanded and extended the theory of the Holmberg Effect, it is important to take his original study and try to reproduce his results with companions that we are sure are actually close to and gravitationally interacting with the edge-on spiral.

My test of the physical basis of the Holmberg Effect makes use of Holmberg's original sample of 62 highly inclined spiral galaxies. This sample was down-selected from a combination of 174 barred and unbarred spiral galaxies of types S0, Sa, Sb, and

Sc from Holmberg's (1958) Catalog and 38 spirals from de Vaucouleurs (1964). All galaxies have a major-axis diameter ≥ 5'.0, a minimum physical diameter of 0.6 kpc, and a limiting absolute (photographic) magnitude of -10.6 mag. From these galaxies were chosen spirals with an edge-on orientation, chosen to have a diameter ratio ≤ 0.53. This corresponds to an inclination ≤ 30^{o}. The limiting distance modulus for his sample was 31.2 mag. Also important in determining the sample was the distance away from a large galaxy or separation (s), compared to the radius (r) of the survey area. If $s > 2r$; $r < s < 2r$ and the mass of the galaxy is less than $1/5^{th}$ the mass of the primary system; or if $s < r$ and the mass is less than $1/25^{th}$ of the primary galaxy, then the galaxies remained in the sample.

To repeat Holmberg's study in a modern context, we searched the NASA/IPAC Extragalactic Database (NED) for companions projected inside of a search area with a radius of 50 kpc from the center of the target galaxy. NED is an excellent database which searches several sky surveys. All of the images retrieved for the Holmberg Effect section of this paper were from Palomar's Deep Sky Survey (DSS). Images of the parent galaxies with their companions circled are seen in Figure 5. Since NED only uses radii in arcminutes as a search constraint, it was necessary to determine a scale to convert kpc to arcminutes. I determined the scale for each target galaxy (and therefore the companions, since it is dependent on redshift) using the Virgo Infall Only Scale from NED. A list of target galaxies, scales, apparent companions (including background galaxies), radial velocity confirmed companions, the names of these confirmed companions, their separations from the parent galaxy, and their position angles can be found in Table 1 at the end of the chapter.

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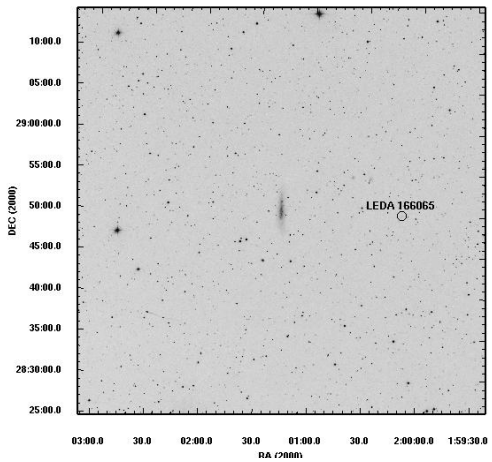

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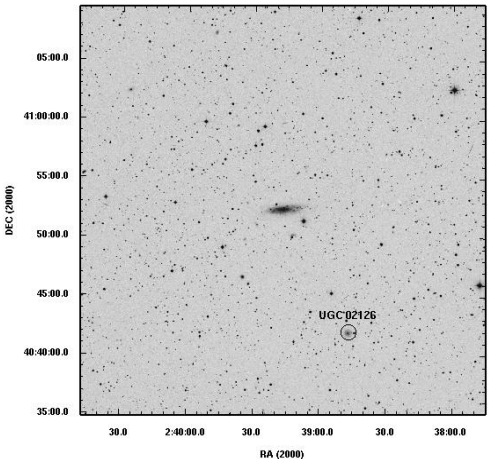

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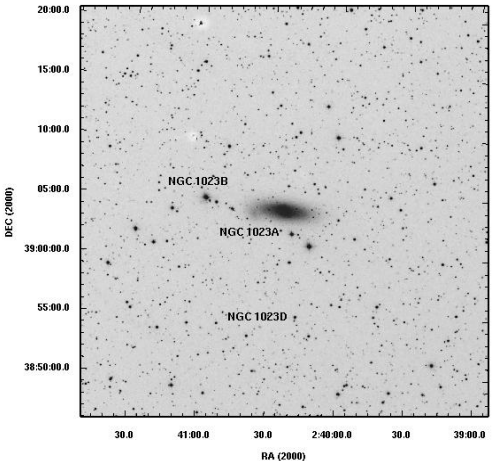

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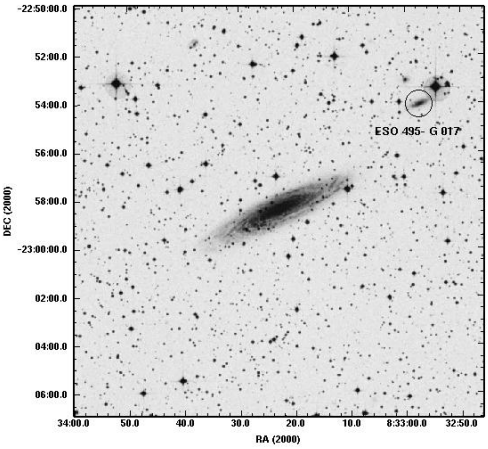

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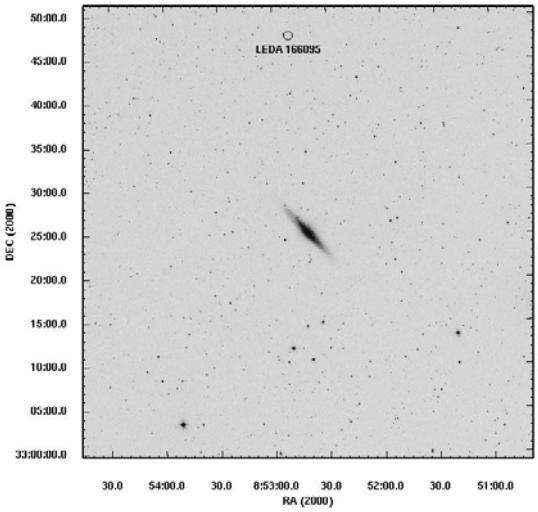

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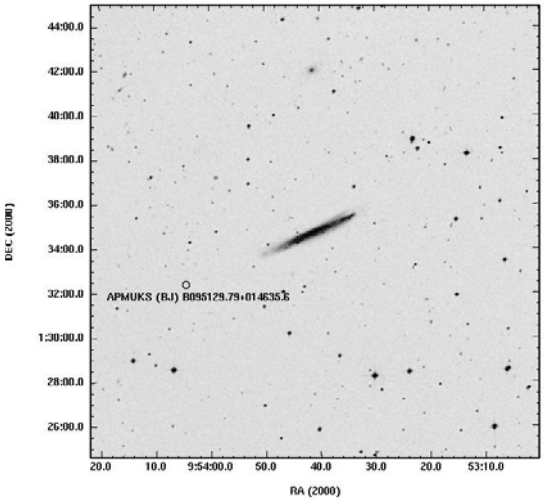

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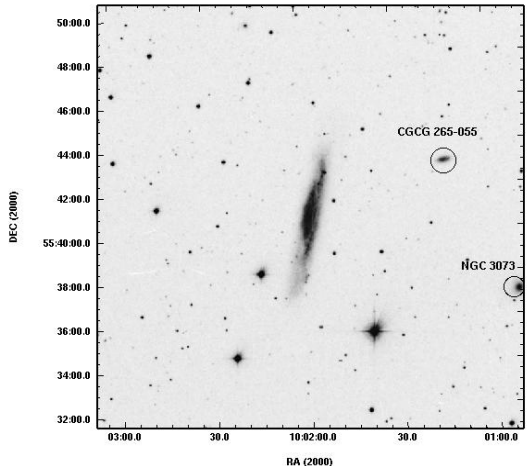

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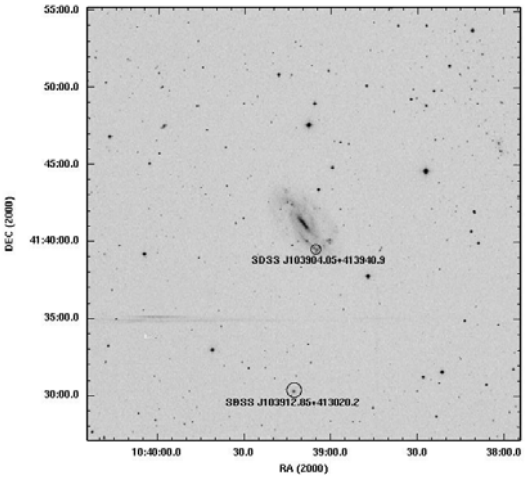

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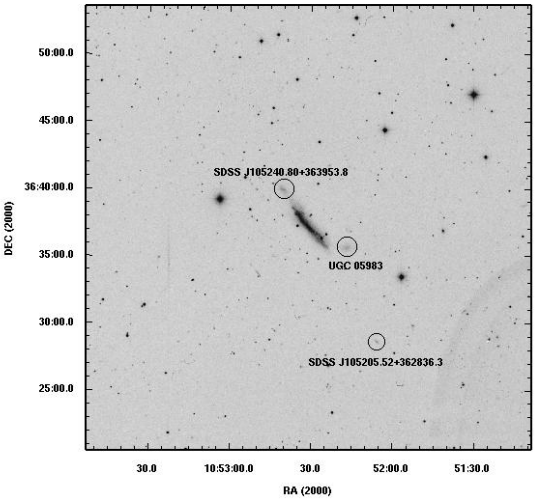

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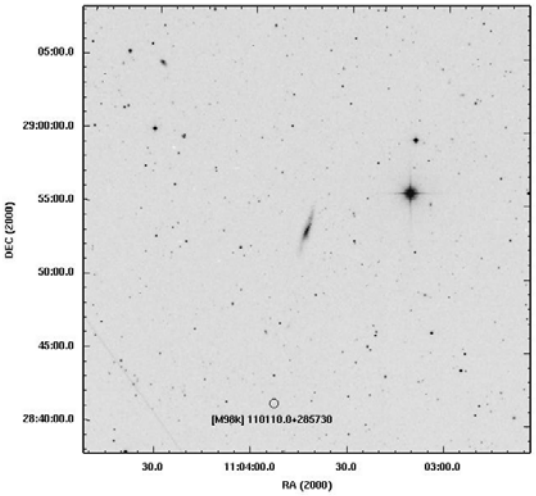

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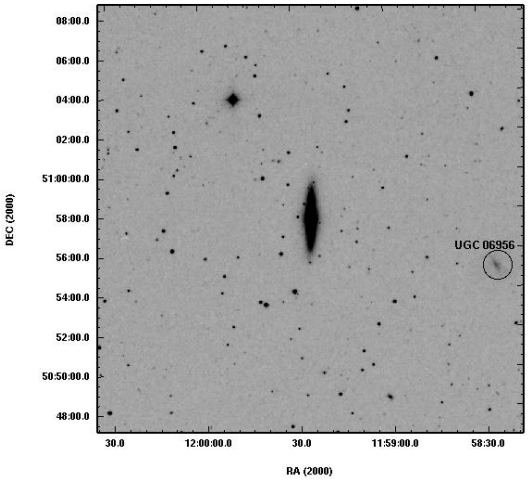

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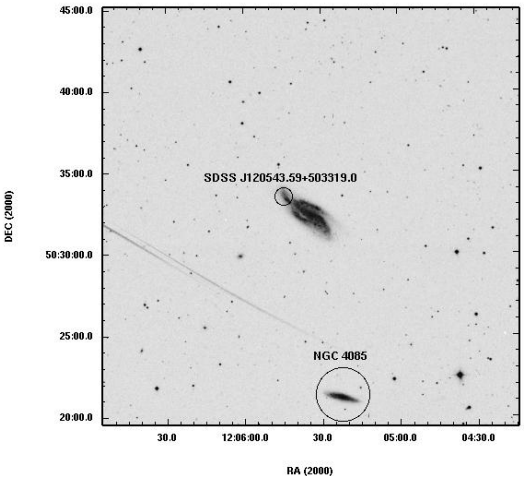

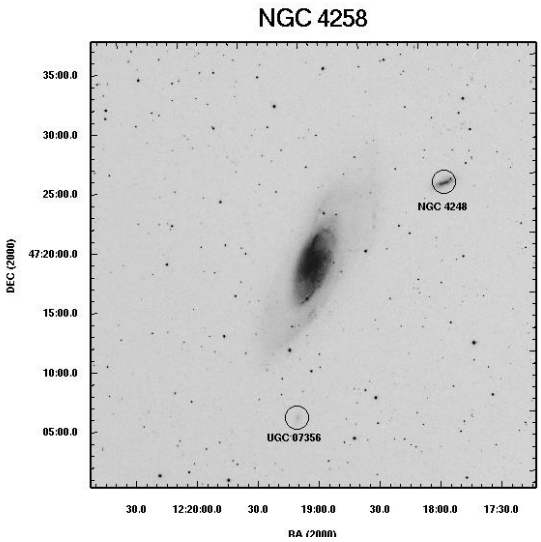
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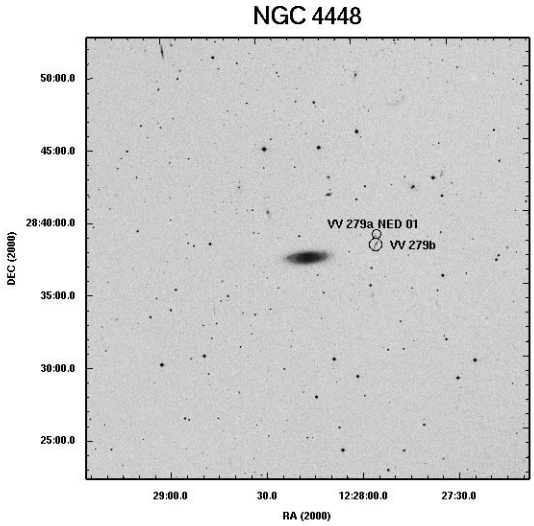
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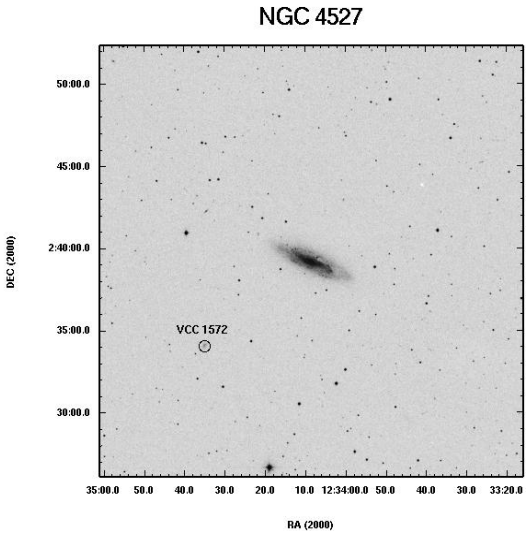
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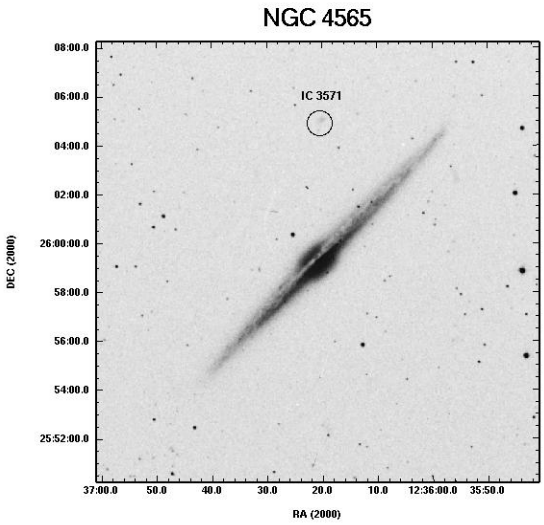
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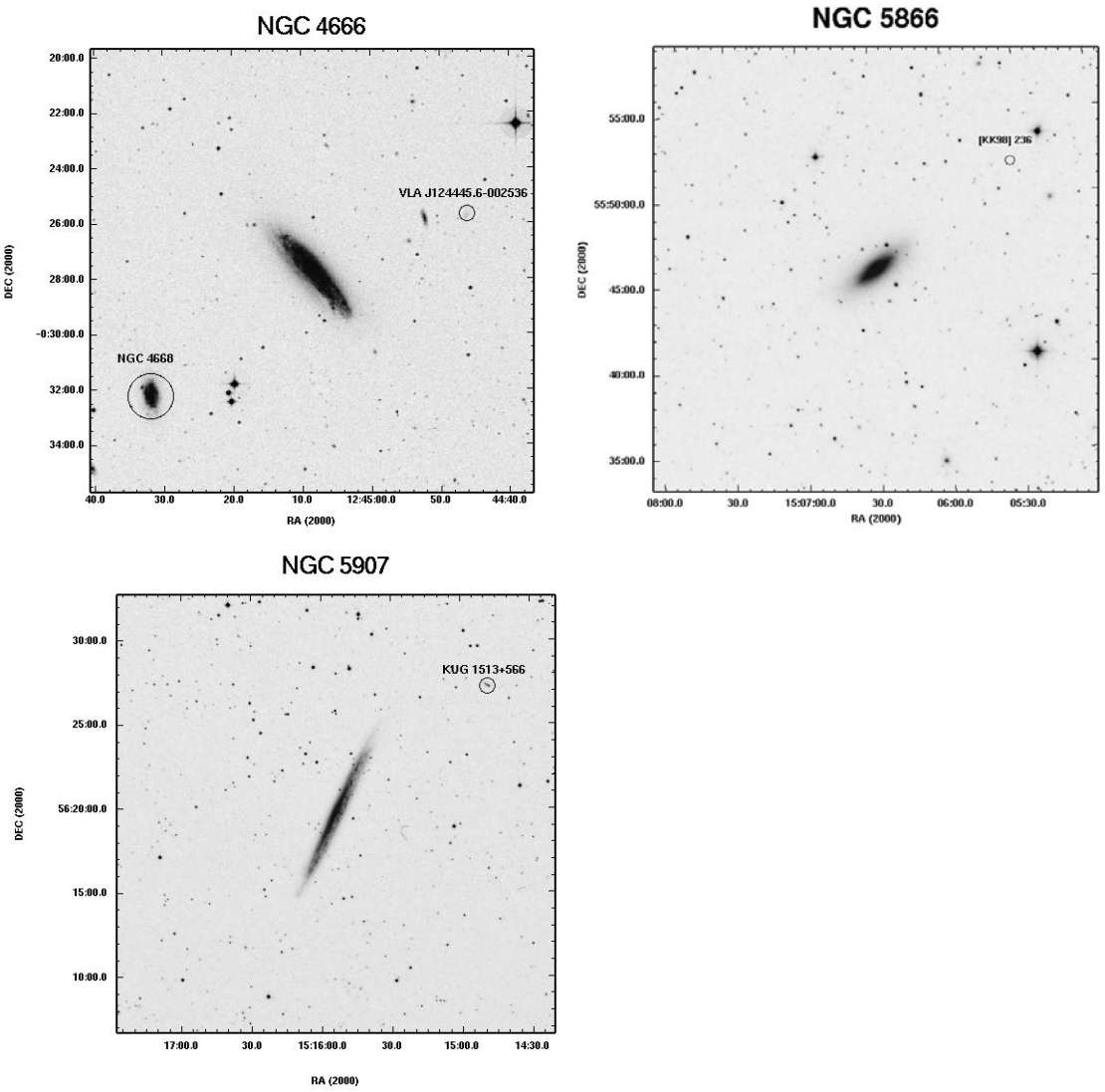


Figure 5: 50 kpc snapshots of edge-on galaxies and their radial velocity companions. All companions were within ±1000 km/s from their primary galaxy.

All companions having a published radial velocity ±1000 km/s of the primary galaxy's radial velocity were retained as physically associated radial velocity companions. These companions are listed in Table 2 at the end of the chapter. This removes the error of background contamination. The problem we have now is not contamination, but perhaps incompleteness, seeing as we may have removed too many of the probable companions. Not all nearby galaxies have a measured, published redshift, and we removed all galaxies without a published redshift from our list of physical

companions. Statistically, however, this should not affect us. It may change the average number of companions around a highly inclined galaxy, but since it is unlikely that there is a bias in the position angle of the companions that we may have removed, it should not change the position angle data. This may not be true if radial velocity data was only determined for bright galaxies, which would produce a mass-dependent bias. Assuming this is not the case, by averaging over the sample, we create an uncontaminated angular distribution function that should statistically represent all companions. It is unusual that there was a bias to begin with, since background galaxies should be uniformly distributed and not make a fake signal. However, for some reason that does not appear to be explained through physical means, getting rid of background contamination has changed the outcome of the experiment. Perhaps there was some bias in Holmberg's sample of background galaxies because several companions in the 0^o - 10^o range were obscured by the disk (either behind the disk or in the disk). An extra test that is beyond the scope of this paper would be to try to reproduce this fake signal using the same background galaxies that Holmberg originally put into his plot (Figure 4). This would, however, be difficult, since Holmberg did not publish which galaxies he considered as background galaxies. Any comparison of the background signal would be partially guesswork.

After determining physical companions for the parent galaxies of Holmberg's sample, we measured the position angle of each companion with respect to the plane of the edge-on spiral. The measuring was done in Aladin, using the "draw" tool. First, I measured the angle that the major axis of the spiral made with what Aladin considered to be "horizontal" and then measured the relative position angle of the companion galaxy. By convention, companions directly above and below the nucleus of the primary galaxy

have a position angle of 90°, and those that are seen along an extension of the major axis of the galaxy have a position angle of 0°. To increase the statistical significance of the event, all data is folded into one (0-90°) quadrant (see Figure 6).

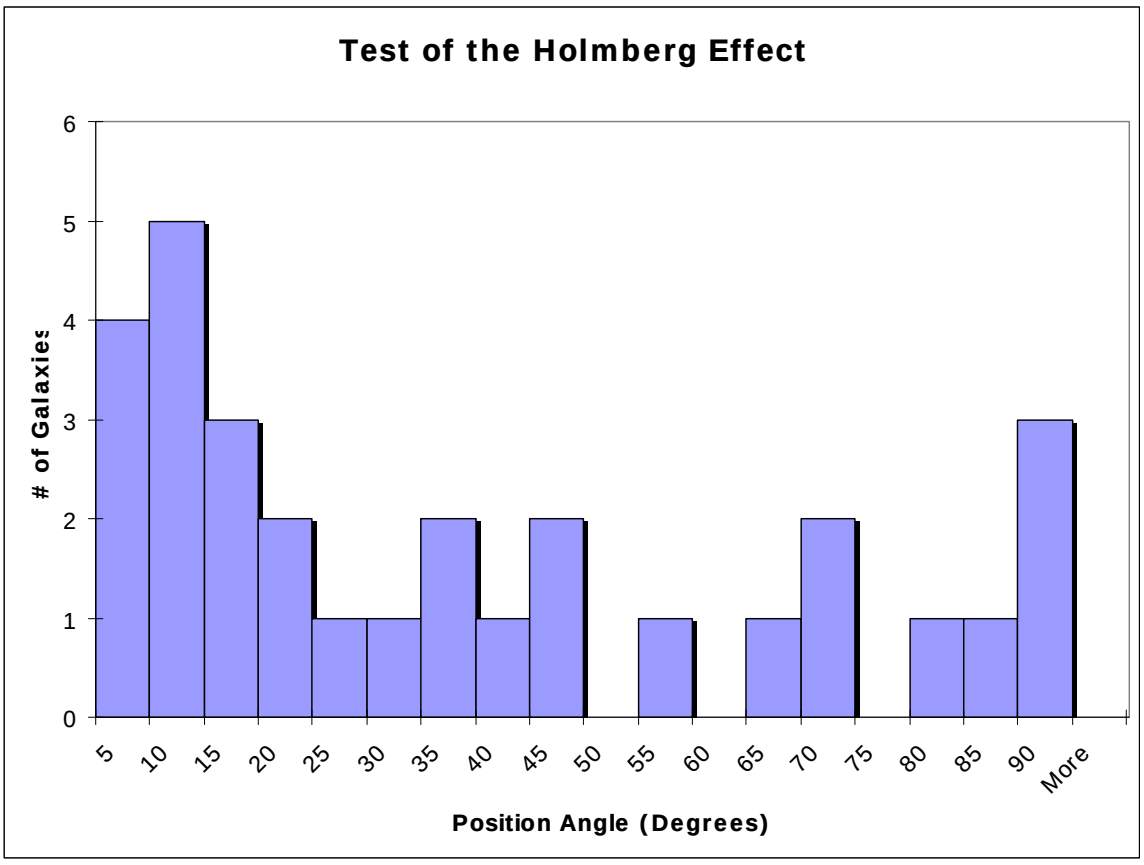


Figure 6: A histogram of the position angle distribution of radial-velocity confirmed companions around Holmberg's original edge-on spirals.

Out of Holmberg's 62 edge-on spiral galaxies, 9 of them were too close to use for statistical comparison. The closer to earth a target is, the larger an angle on the sky it takes up. Because of this angle disparity, closer galaxies have many more galaxies associated with them than galaxies at far distances. Of the other 53 spirals, only 19 have any radial velocity confirmed companions. These 19 galaxies and their companions are displayed in Figure 5.

As is seen in Figure 7, there is apparently little statistically significant anisotropy in the position angles of companions around edge-on spirals. This is shown in a different way in Figure 6. Figure 6 shows the distribution of position angles in the (0-90^o) quadrant. It is clear that for the most part the companions are isotropically distributed,

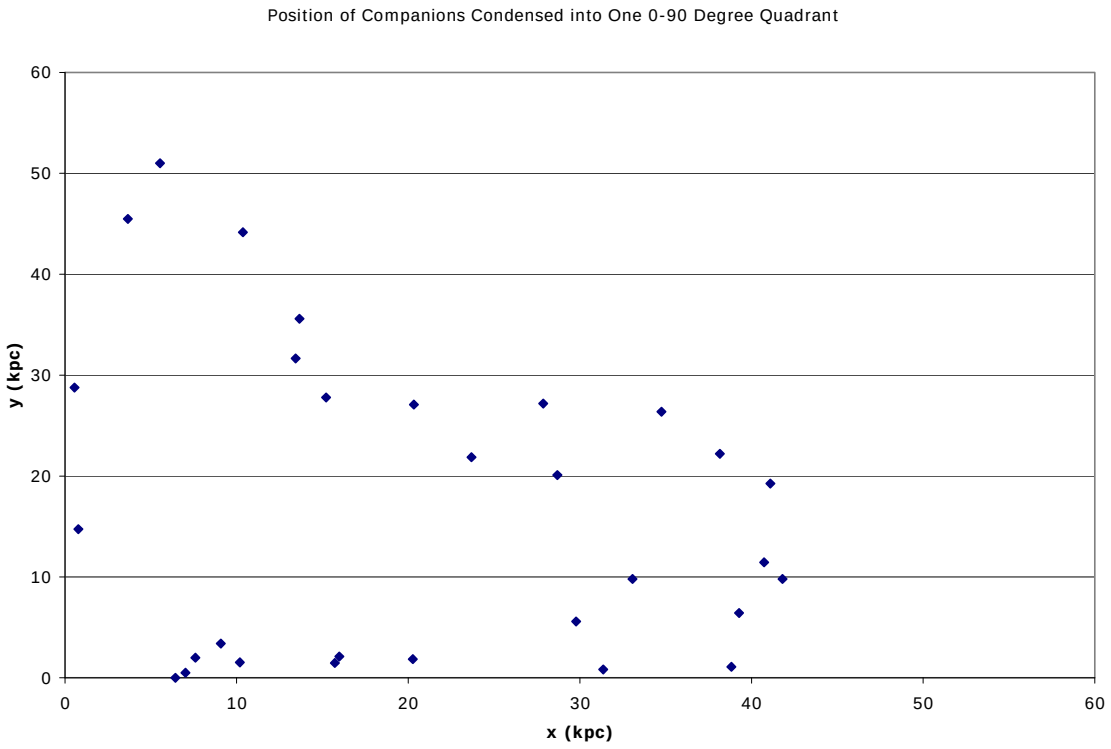


Figure 7: A plot showing the positions of the radial-velocity confirmed companions to edge-on spirals used by Holmberg in his original 1969 study. The x- and y- axes are both distance away from the center of the primary galaxy in kpc.

although there is a small, statistically insignificant signal that shows if anything, companions are more likely to be near the plane of the galaxy (PA = 0^o – 10^o). The Holmberg effect does not show up at all, even using Holmberg's original sample of edge-on spirals. If anything, the opposite of the Holmberg effect is true, but considering the small number of data points we have, we cannot draw any conclusions. Perhaps further study of the position angles of radial velocity confirmed companions around other edge-on spirals (with Holmberg's sample included) will help to illuminate this issue. Also, as

the NED database continues to expand and new redshift surveys are included, this same study can be retried, and more companions will be included. Another way of extending this study would be to determine the number of apparent companions that have radial velocity data at all. When this number is compared with the number of these apparent companions that have a radial velocity within 1000 km/s of the parent galaxy, it tells us something about the completeness of our sample. If all of the apparent galaxies that have velocity data are also confirmed companions of the primary galaxy, then when more redshift data is included in the NED database, other galaxies will probably be shown to be confirmed companions. However, if there are many galaxies with radial velocities considerably different than ±1000km/s from the primary, it is reasonable to assume that most of the companions (though we may miss some) can be confirmed through the radial velocity technique.

Table 1:

NGC #	Scale ('/50kpc)	# of Apparent Companions	# of Radial Velocity Companions	names of RVCs	separations	Position Angle (degrees)
784	49.5	83	1	LEDA 166065	14.6'	87
891	19.6	23	0			
908	9.5	31	0			
1003	17.3	21	1	UGC 02126	11.9'	67
1023	17.2	15	3	NGC 1023A	2.7'	14.6
				NGC 1023B	7.0'	5.2
				NGC 1023D	9.9'	88.9
1337	11.7	30	0			
1507	17.6	24	0			
2541	18.4	25	0			
2613	8.5	3	1	ESO 495- G 017	7.3'	13.2
2683	25.9	79	1	LEDA 166095	22.6'	37.2
2715	7.9	3	0			
2841	15.6	26	0			
3003	8	7	0			
3044	10.2	61	1	APMUKS(BJ) B095129.79+014635.6	6.4'	1.5
3079	9.6	10	2	*CGCG 265-055	6.5'	53.1
				NGC 3073	9.85'	83.8
3198	15.1	26	0			
3254	8.6	3	0			
3301	9	6	0			
3319	14	22	2	SDSS J103904.05+413940.9	1.8'	0
				SDSS J103912.85+413020.2	10.9'	44.3
3432	16.5	38	3	SDSS J105240.80+363953.8	3.4'	8.5
				UGC 05983	3.2'	20.5
				SDSS J105205.52+362836.3	10.0'	10.6
3495	11.1	10	0			
3510	15.2	33	1	[M98k] 110110.0+285730	12.1'	9.3
3521	16	109	0			
3556	13.7	28	0			
3675	13.1	18	0			
4026	10.8	12	1	UGC 06956	9.8'	76.8
4064	13.1	8	0			
4088	12.8	23	2	SDSS J120543.59+503319.0	1.8'	4.1
				NGC 4085	11.3'	30.2
4096	16	23	0			
4178	27.6	69	0			
4236	46.7	73	0			

NGC #	Scale ('/50kpc)	# of Apparent Companions	# of Radial Velocity Companions	names of RVCs	separations	Position Angle (degrees)
4258	18.7	34	2	UGC 07356	12.9'	16.5
				NGC 4248	13.1'	35
4293	13.1	12	0			
4448	15.2	27	2	VV 279b	4.8'	5.3
				VV 279a NED 01	4.9'	7.5
4517	10.8	73	0			
4527	13.1	18	1	VCC 1572	8.3'	61.3
4536	6.8	23	0			
4565	9	10	1	IC 3571	5.8'	42.7
4594	12.4	14	0			
4666	8	30	2	VLA J124445.6-002536	6.1'	69
				NGC 4668	7.3'	85.4
4710	13.1	15	0			
4856	9.4	7	0			
5204	26.5	91	0			
5746	6.8	22	0			
5866	13	19	2	[KK98] 236	10.1'	1.6
				NGC 5866A	11.0'	15.7
5879	11.7	23	0			
5907	13	11	1	KUG 1513+566	11.8'	25.1
6015	11	1	0			
6503	34	33	0			
7331	12.5	17	0			
7361	11	44	0			
7640	22.6	12	0			
7814	11.3	19	0			

Table 2:

Names of Radial Velocity Companions	PA (degrees)	PA (radians)	separations (arcminutes)	Scale (arcminutes/50kpc)	separations (kpc)	x (kpc)	y (kpc)
LEDA 166065	87	1.518	14.6	49.5	14.7	0.8	14.7
UGC 02126	67	1.169	11.9	17.3	34.4	13.4	31.7
NGC 1023A	14.6	0.255	2.7	17.2	7.8	7.6	2.0
NGC 1023B	5.2	0.091	7	17.2	20.3	20.3	1.8
NGC 1023D	88.9	1.552	9.9	17.2	28.8	0.6	28.8
ESO 495- G 017	13.2	0.230	7.3	8.5	42.9	41.8	9.8
LEDA 166095	37.2	0.649	22.6	25.9	43.6	34.8	26.4
APMUKS(BJ) B095129.79+014635.6	1.5	0.026	6.4	10.2	31.4	31.4	0.8
*CGCG 265-055	53.1	0.927	6.5	9.6	33.9	20.3	27.1
NGC 3073	83.8	1.463	9.85	9.6	51.3	5.5	51.0
SDSS J103904.05+413940.9	0	0.000	1.8	14	6.4	6.4	0.0
SDSS J103912.85+413020.2	44.3	0.773	10.9	14	38.9	27.9	27.2
SDSS J105240.80+363953.8	8.5	0.148	3.4	16.5	10.3	10.2	1.5
UGC 05983	20.5	0.358	3.2	16.5	9.7	9.1	3.4
SDSS J105205.52+362836.3	10.6	0.185	10	16.5	30.3	29.8	5.6
[M98k] 110110.0+285730	9.3	0.162	12.1	15.2	39.8	39.3	6.4
UGC 06956	76.8	1.340	9.8	10.8	45.4	10.4	44.2
SDSS J120543.59+503319.0	4.1	0.072	1.8	12.8	7.0	7.0	0.5
NGC 4085	30.2	0.527	11.3	12.8	44.1	38.1	22.2
UGC 07356	16.5	0.288	12.9	18.7	34.5	33.1	9.8
NGC 4248	35	0.611	13.1	18.7	35.0	28.7	20.1
VV 279b	5.3	0.093	4.8	15.2	15.8	15.7	1.5
VV 279a NED 01	7.5	0.131	4.9	15.2	16.1	16.0	2.1
VCC 1572	61.3	1.070	8.3	13.1	31.7	15.2	27.8
IC 3571	42.7	0.745	5.8	9	32.2	23.7	21.9
VLA J124445.6-002536	69	1.204	6.1	8	38.1	13.7	35.6
NGC 4668	85.4	1.491	7.3	8	45.6	3.7	45.5
[KK98] 236	1.6	0.028	10.1	13	38.8	38.8	1.1
NGC 5866A	15.7	0.274	11	13	42.3	40.7	11.4
KUG 1513+566	25.1	0.438	11.8	13	45.4	41.1	19.3

Chapter 3: The Ring Galaxy Catalog

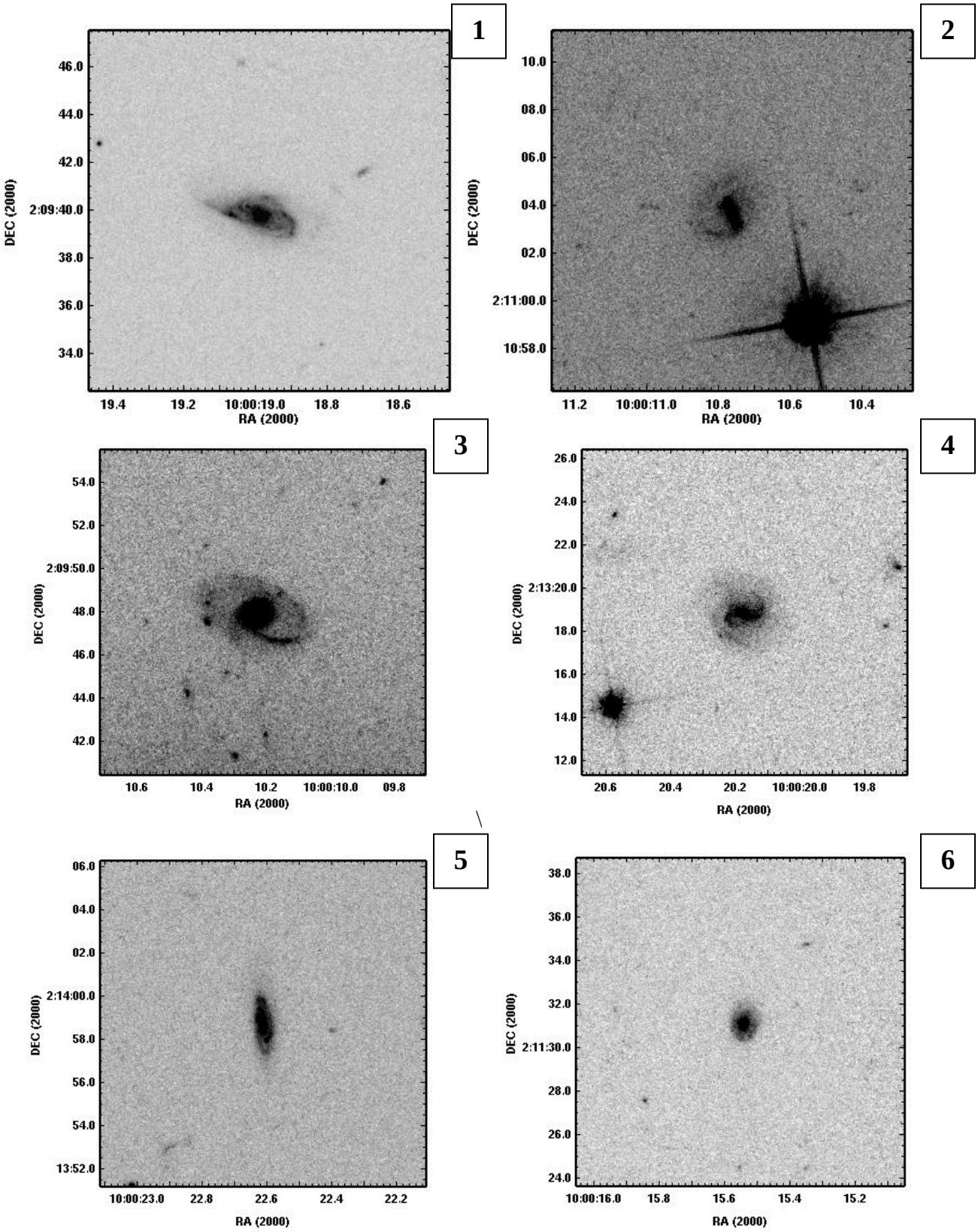
This section details the Ring Galaxy Catalog created from the COSMOS field HST f814w band (*I*-band) data. I created this catalog partly because few ring galaxies are known and have been studied extensively. The most commonly studied ring galaxies are the Cartwheel Galaxy (ESO 350- G 040), and the Lindsay Shapley Galaxy (AM 0644-741). However, as is seen in the catalog (Figure 8), ring galaxies come in different shapes. Although they all take the form of a ring, some have spiral structure, some have no nucleus, and they by no means have exactly the same physical explanation behind their morphology (though we can assume a gravitational interaction of some sort). In order to increase the number of known ring galaxies, to expand our knowledge of rings to a greater redshift, to compare ring galaxies at high redshift with ring galaxies in the nearby universe, and to discover rings in the *I*-band that have data from other bands (the most unique thing about the COSMOS project), I have created this Catalog of Ring Galaxies.

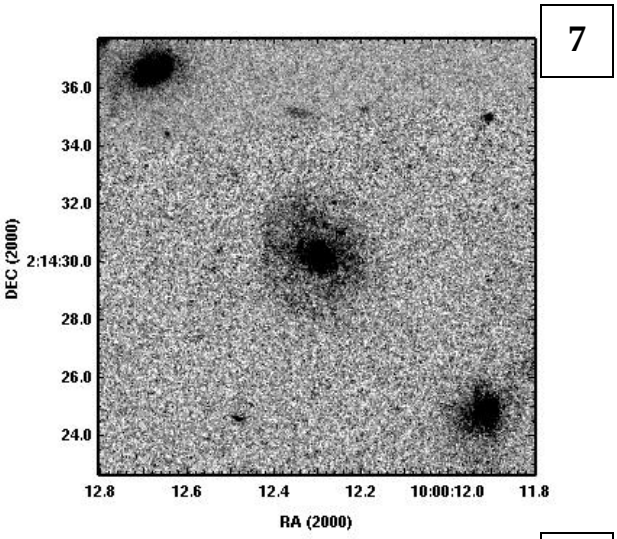
I obtained the COSMOS dataset from the IRSA website http://irsa.ipac.caltech.edu/Missions/cosmos.html. Using the publicly accessible data option, it is possible to download all of the f814w *I*-band images captured by the ACS instrument on the Hubble Space Telescope (HST). This consists of 581 images 5600 pixels wide by 5600 pixels tall. Since the ACS instrument on HST has a pixel size of 15 microns per pixel, this corresponds to an area of 7.06×10^9 microns^2 (7065 meters^2) per image. Using my computer monitor to view these images, I opened them in ds9, which automatically created a field of view such that I could see 1435 x 574 pixels of the entire image. I discovered an average of about 1 possible ring galaxy per image, although rings very densely populated some areas, and other areas contained no ring galaxies at all.

From this 2 degree COSMOS field, I discovered 561 ring candidates. Since the data was split into 581 images, some of these ring candidates were found at the edge of one picture and later in a different one. Sometimes the same galaxy was listed twice, but I estimate that the total distortion of the results due to duplicates and potential rings not actually being classifiable as gravitationally formed ring galaxies is not more than 5 to 10 percent. A list of the candidates, their positions on the sky (in decimal coordinates), e(B-V) determined from Schlegel et al. (1998), photometric redshift (zphot) determined from Mobasher et al. (2007), the minimum and maximum redshift at 95% probability, the absolute *V*-band magnitude, and the logmass are found in Table 3 after the catalog. The logmass is the log (base 10) of the stellar mass in units of solar mass from Mobasher et al. (2007). Mobasher et al. (2007) used a cosmology of $\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$, and h = 0.7. Table 4 presents k, u, g, r, i, and z magnitudes determined from SDSS data, one sigma error in the same k, u, g, r, i, and z magnitudes, the HST f814w magnitude (the images I

searched through were all in this band), and one sigma f814w error. Note that some rings have more than one line of data apply to them due to shredding. Since source extraction often separates galaxies into 2 or more parts, all sections attributed to a single ring should be simply data from different parts of the ring. Averaging the lines of data that apply to a single ring should give you the ring's physical characteristics.

Figure 8: A Catalog of Ring Galaxies from COSMOS. Each snapshot is 15 arcseconds on a side.

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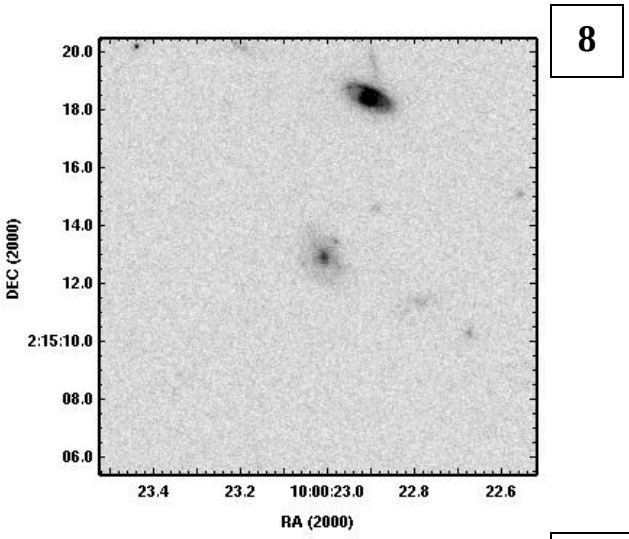
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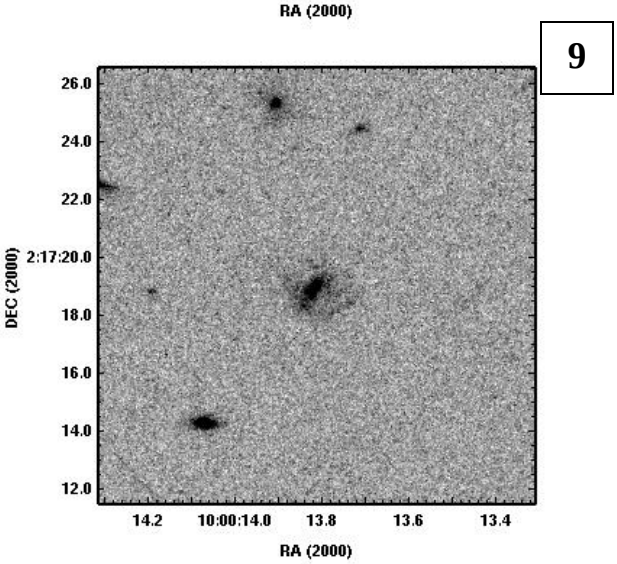
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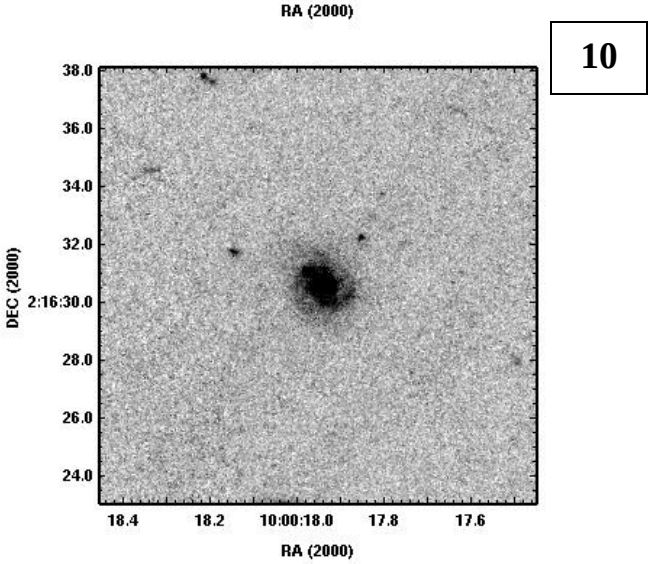
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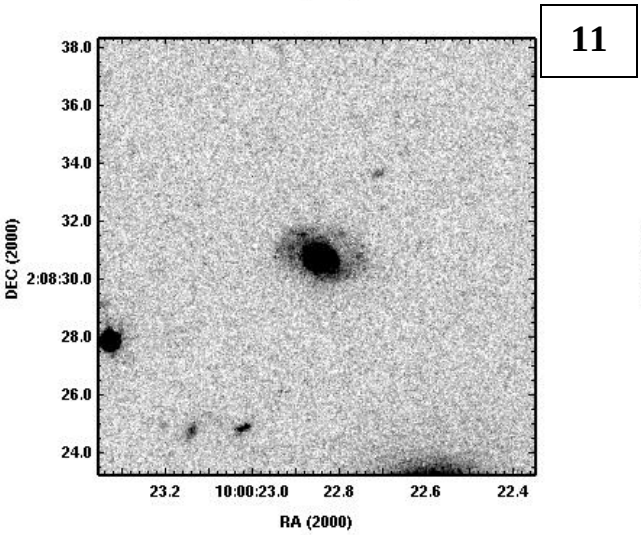
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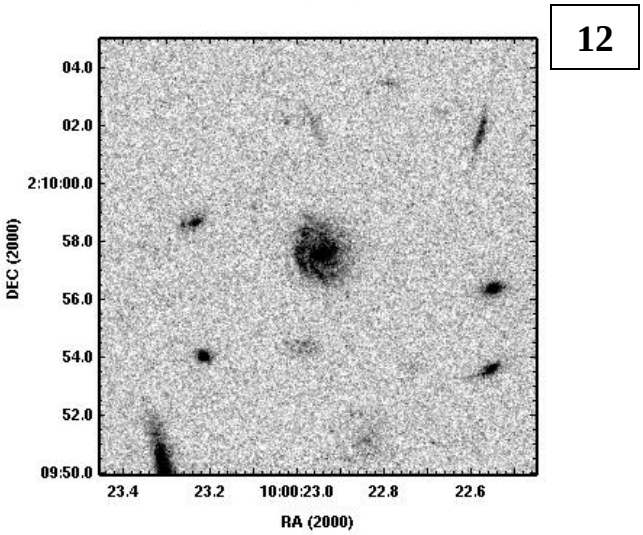
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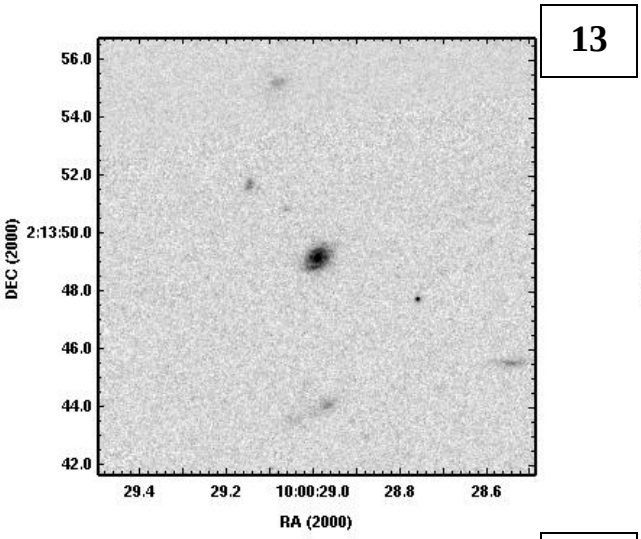
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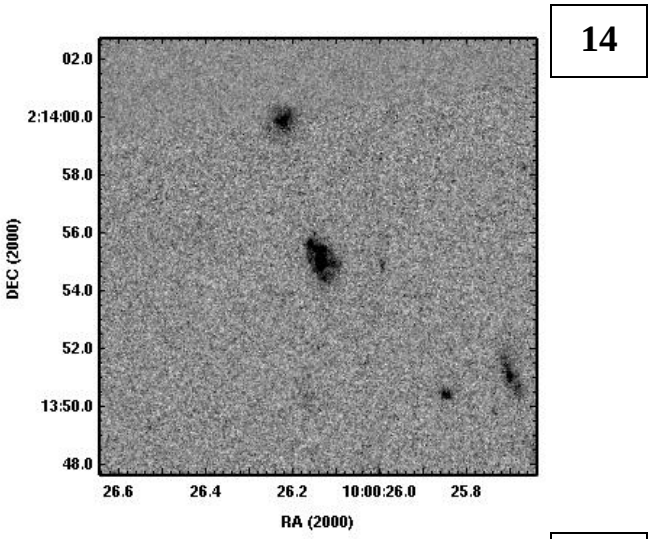
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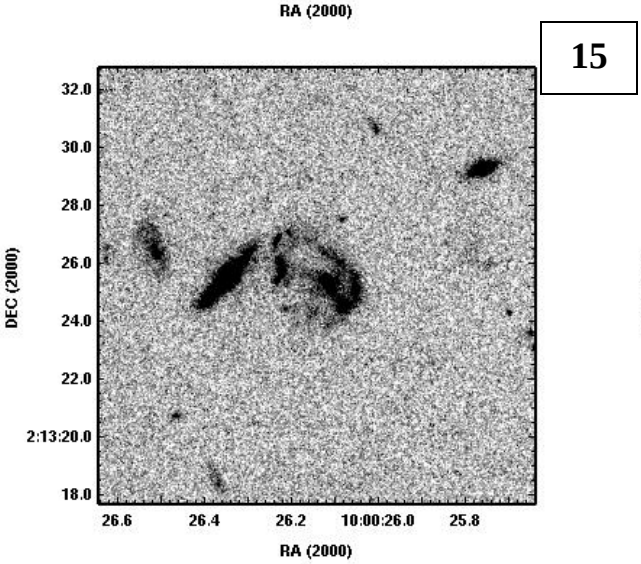
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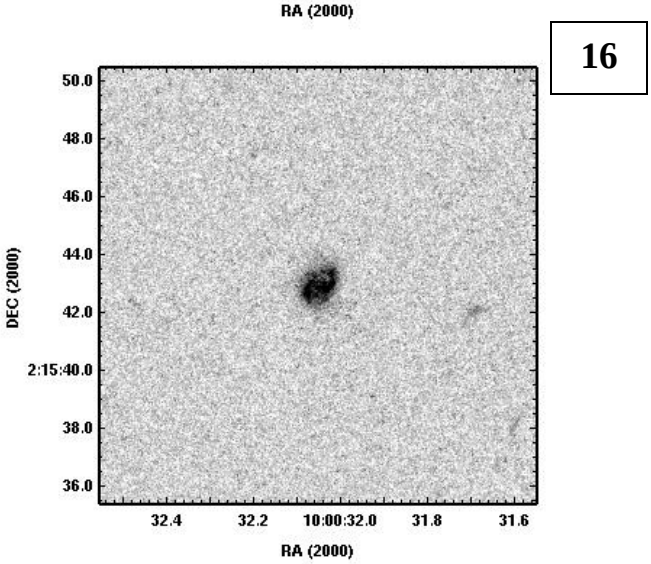
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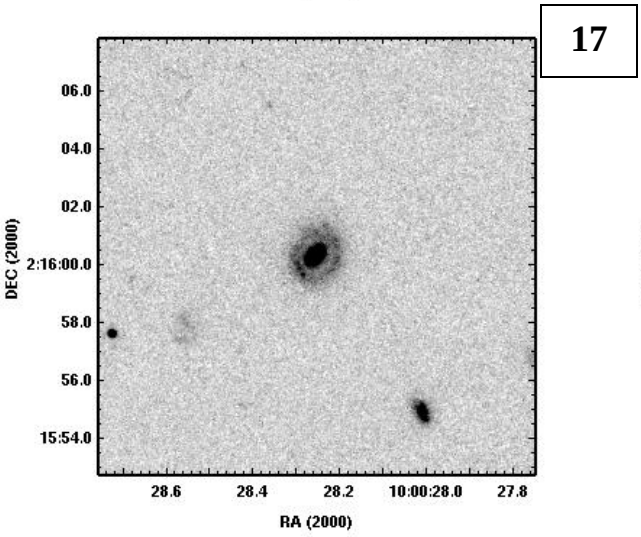
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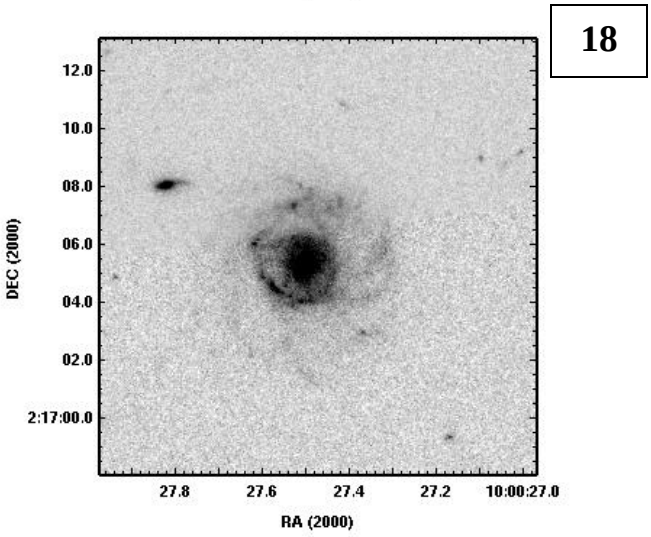
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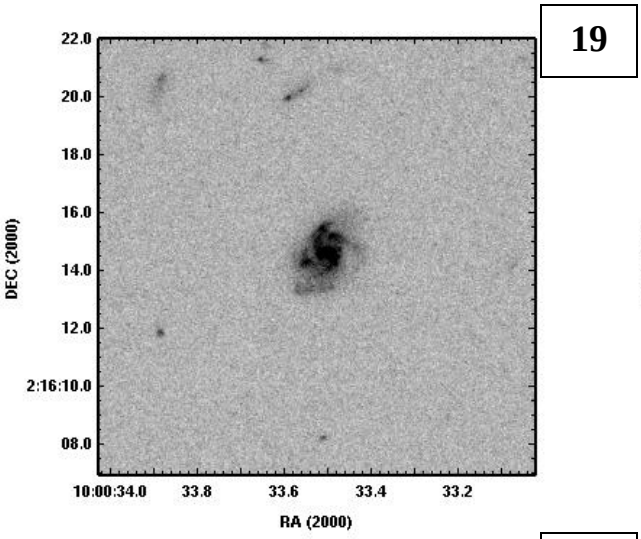
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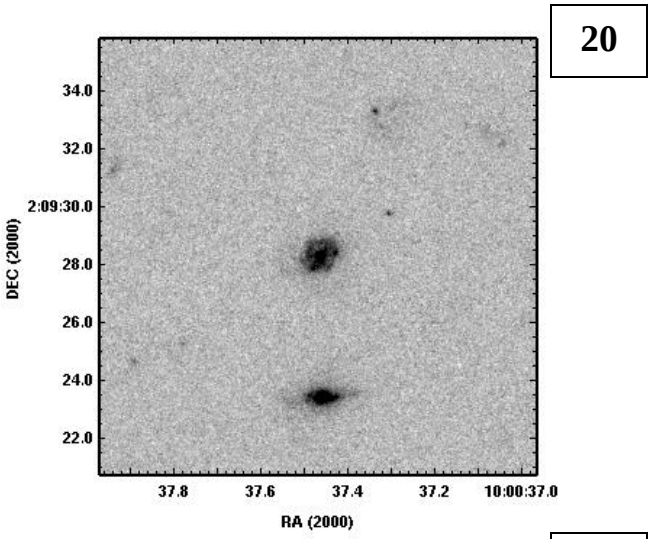
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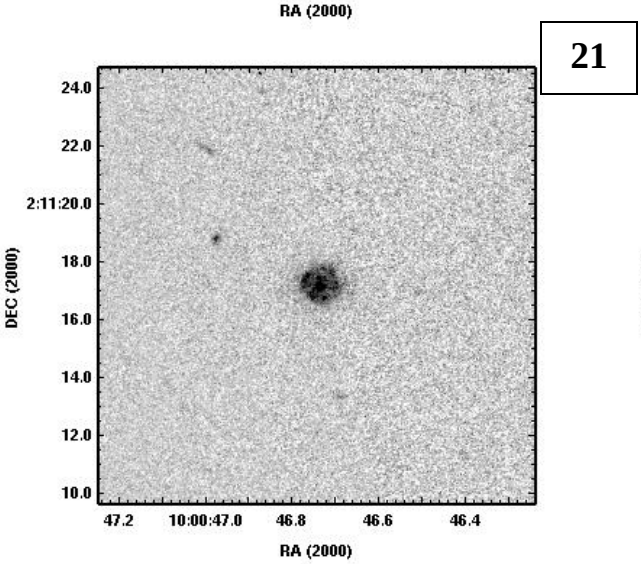
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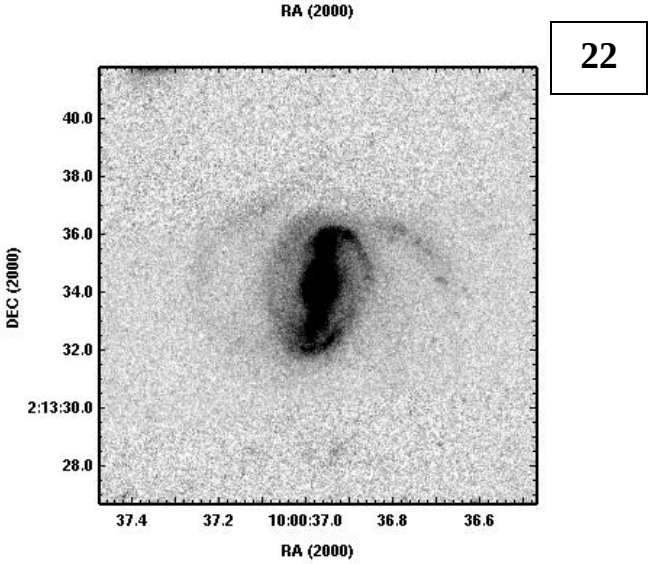
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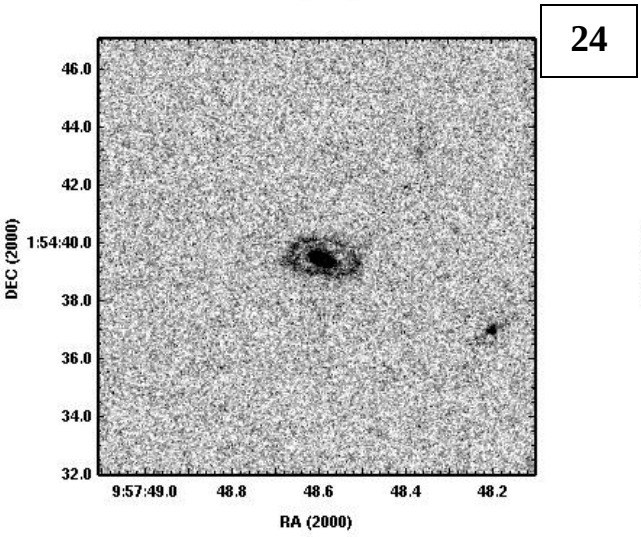
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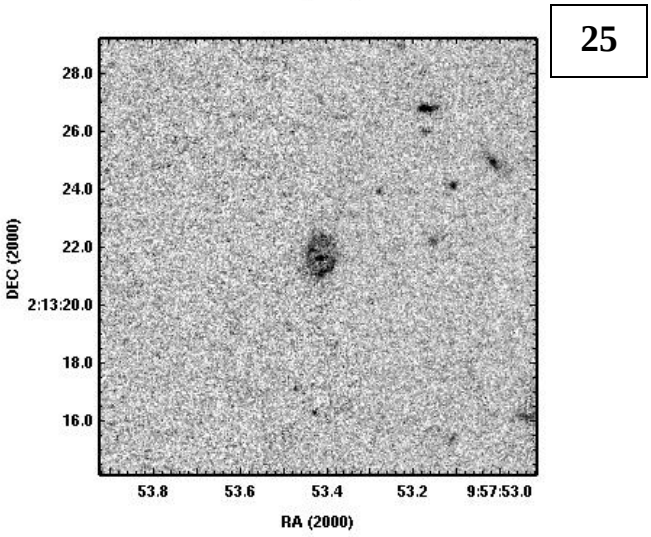
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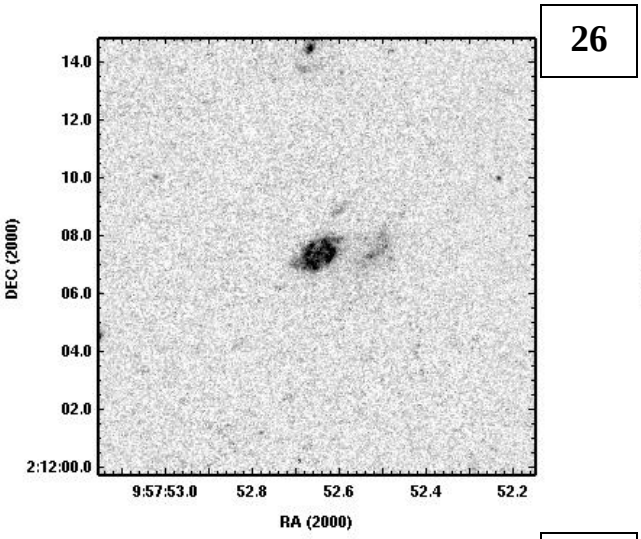
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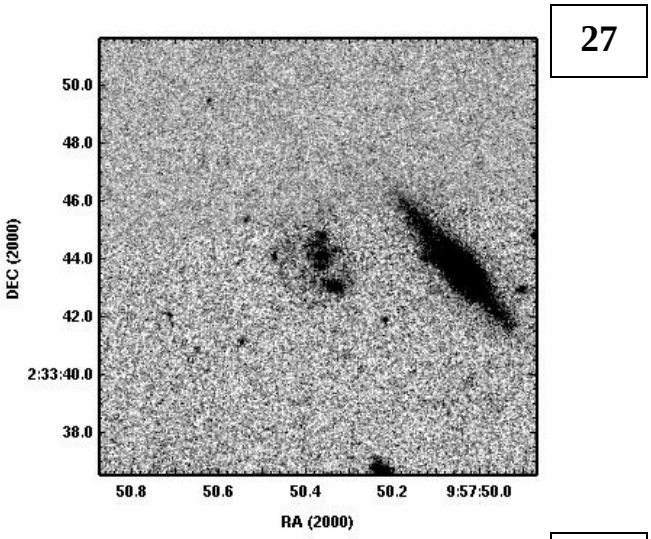
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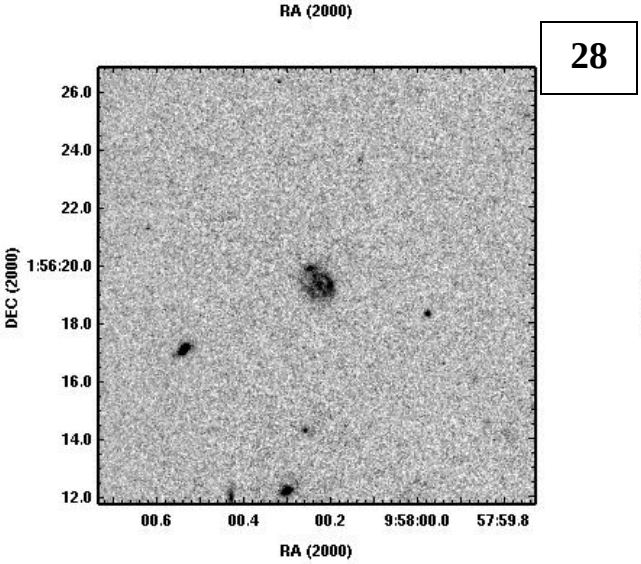
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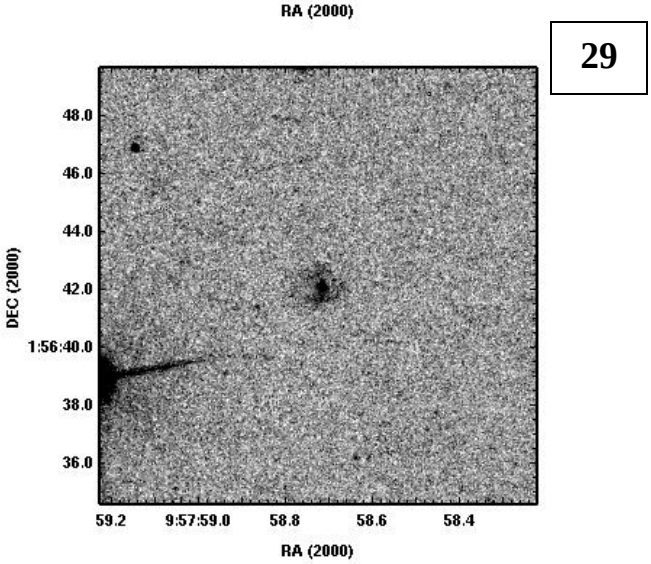
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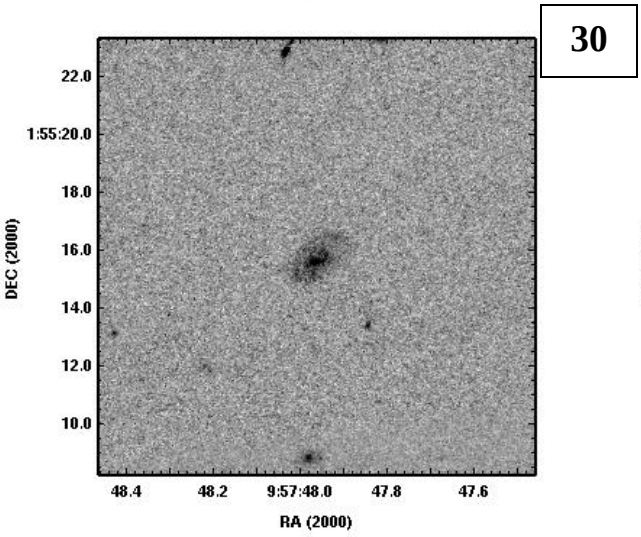
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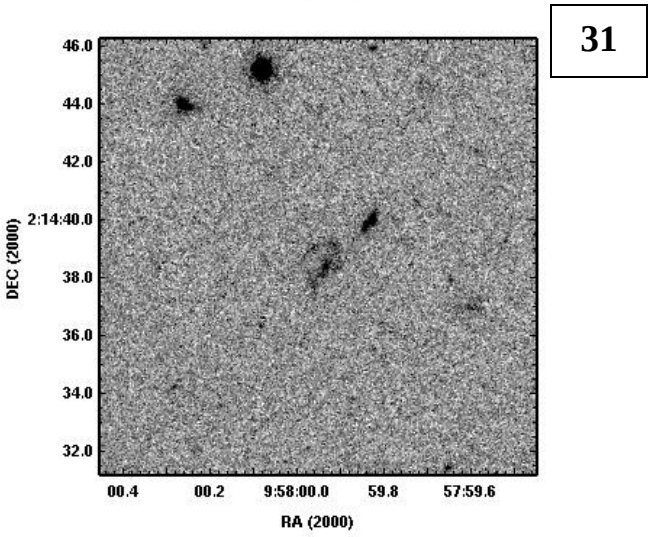
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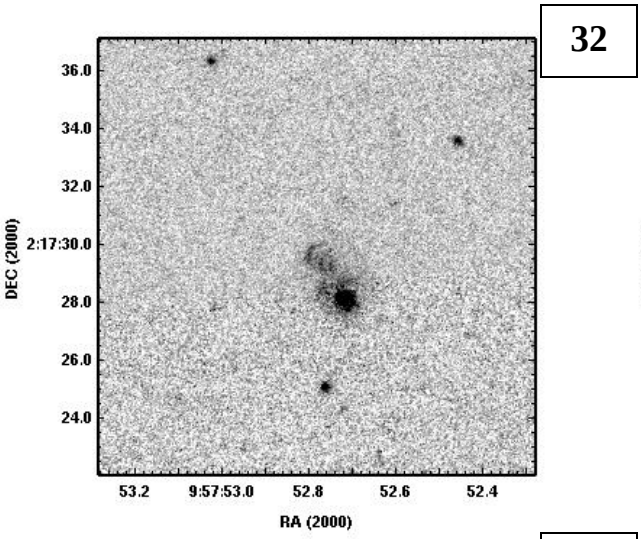
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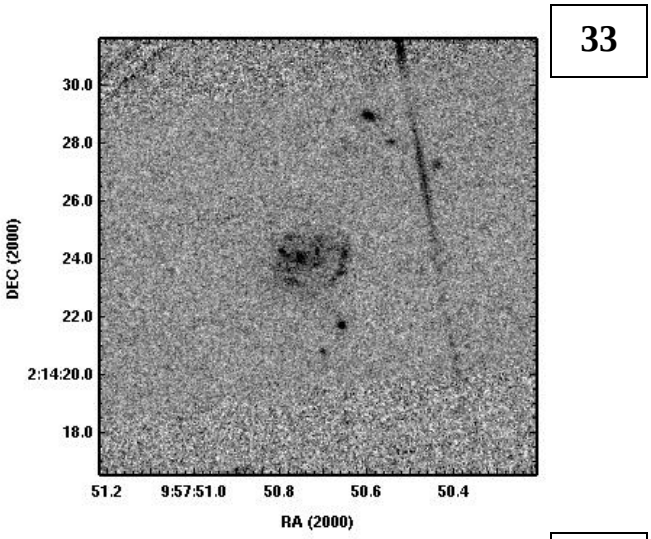
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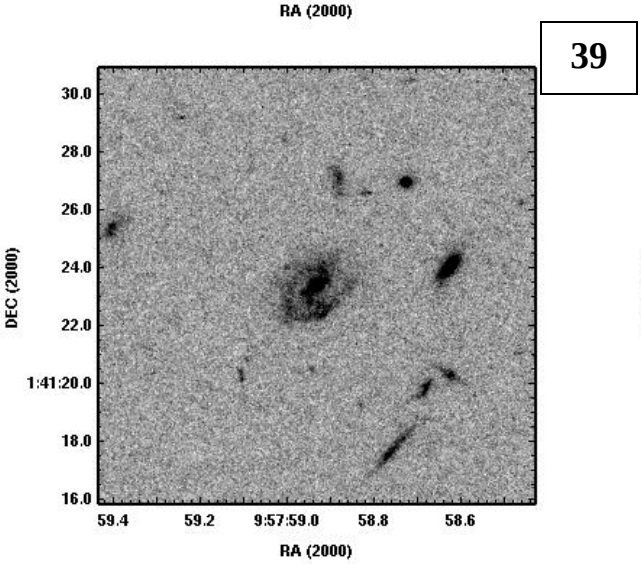
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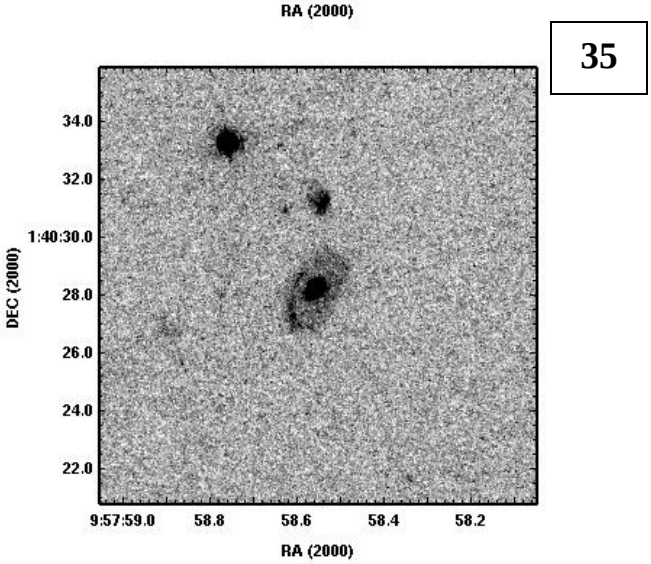
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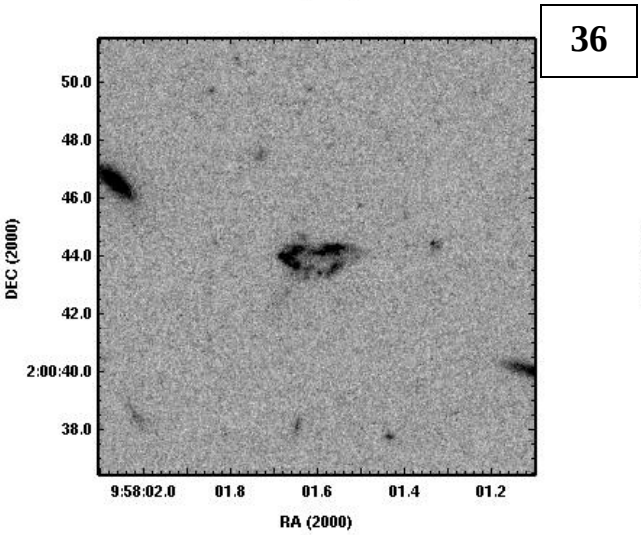
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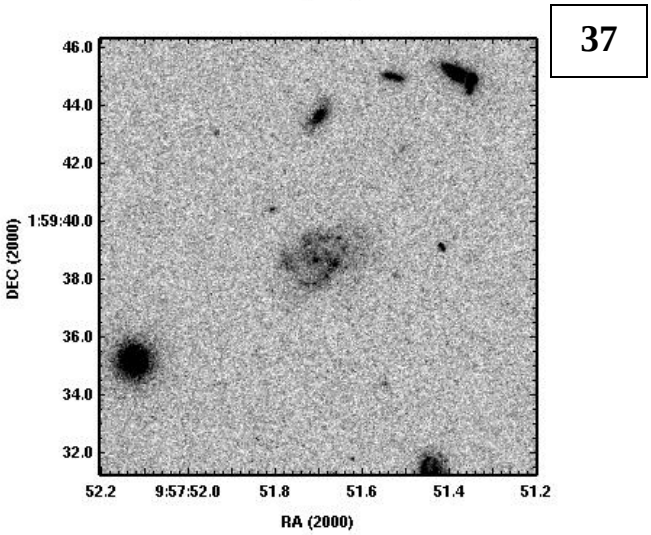
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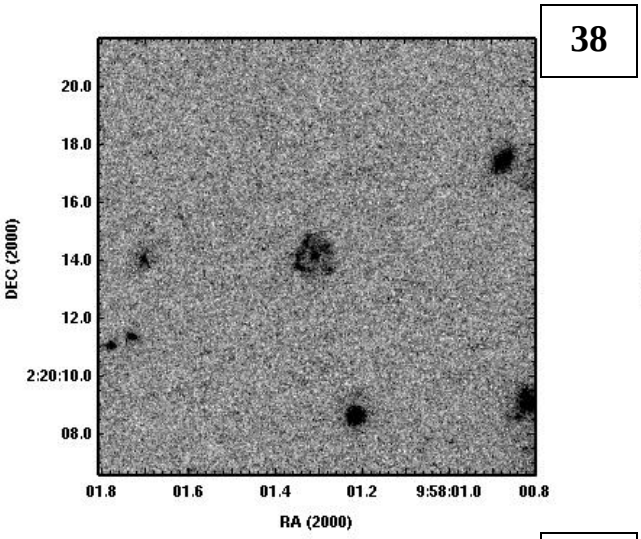
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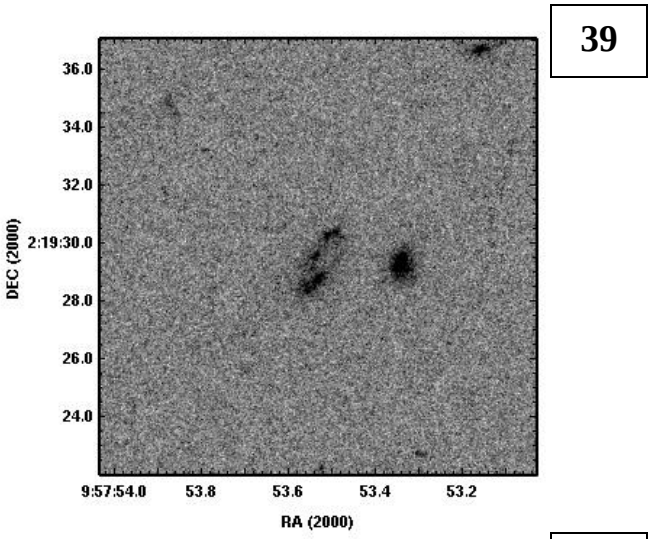
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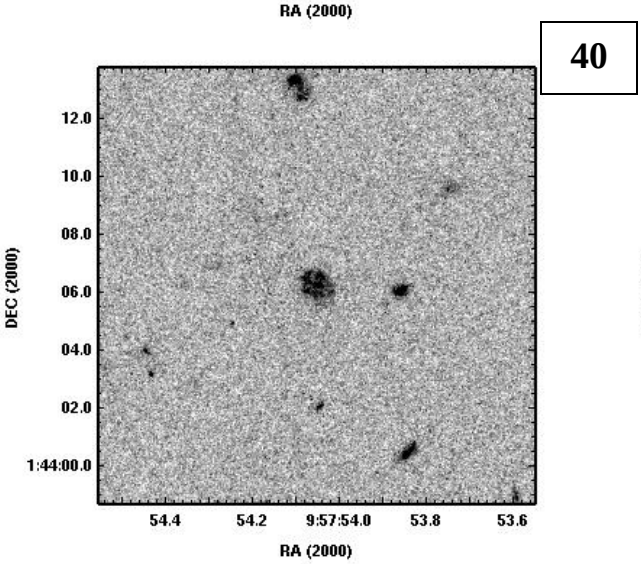
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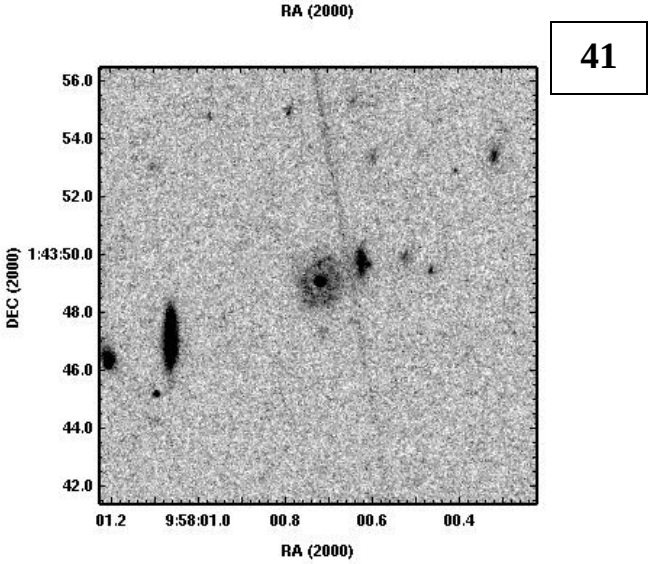
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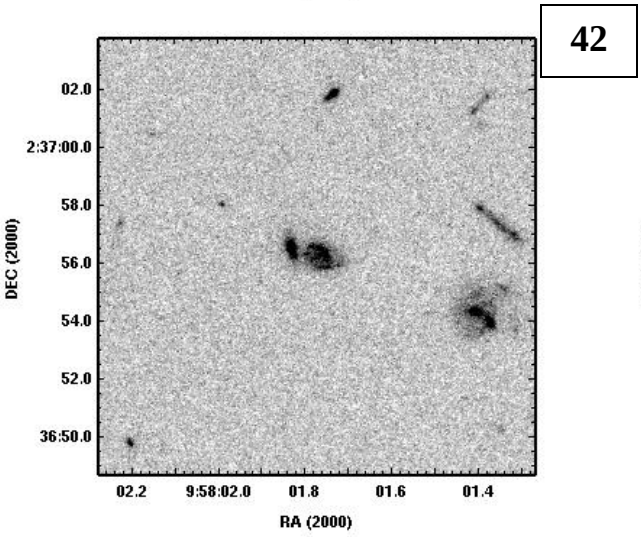
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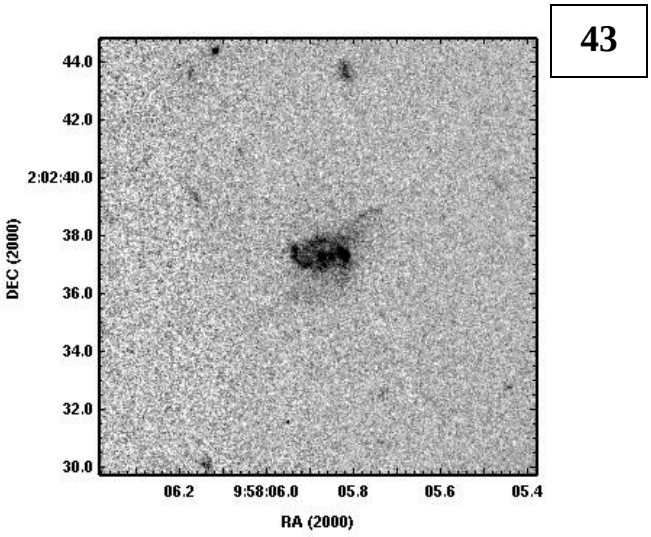
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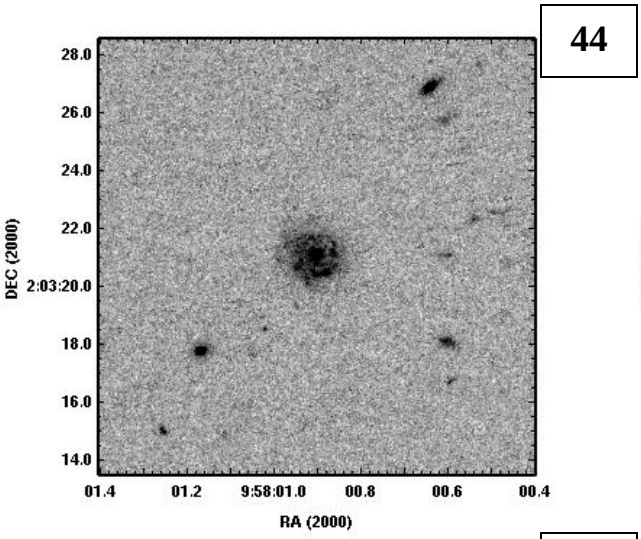
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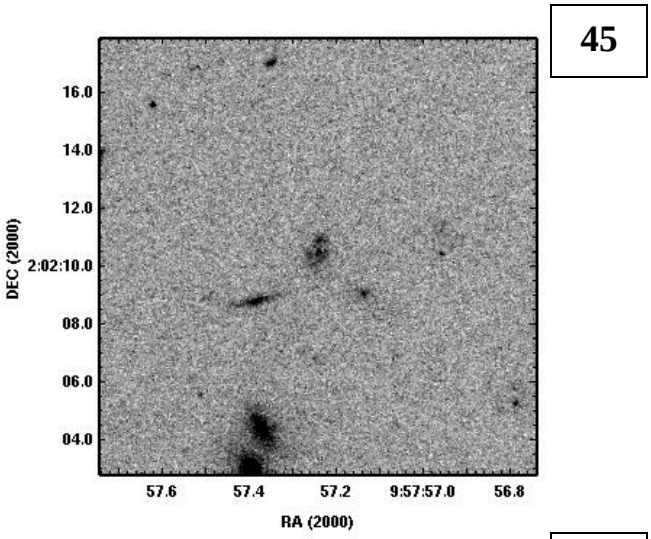
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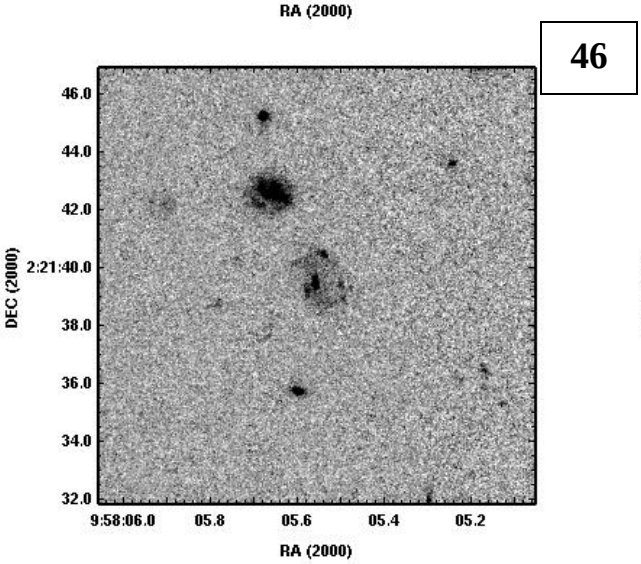
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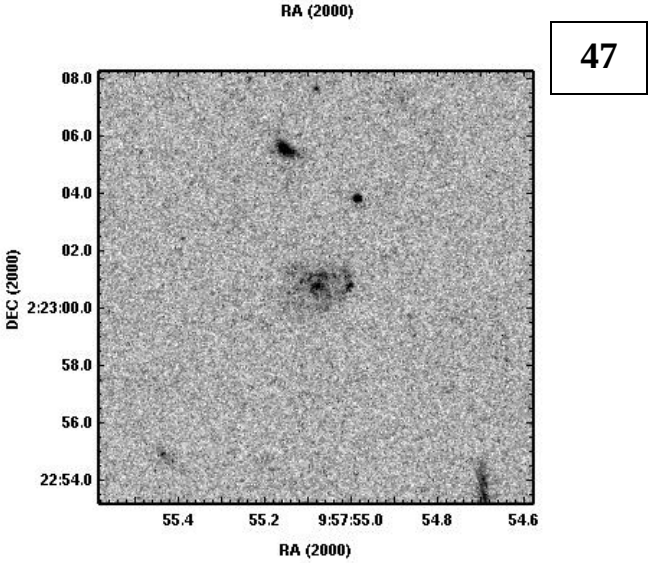
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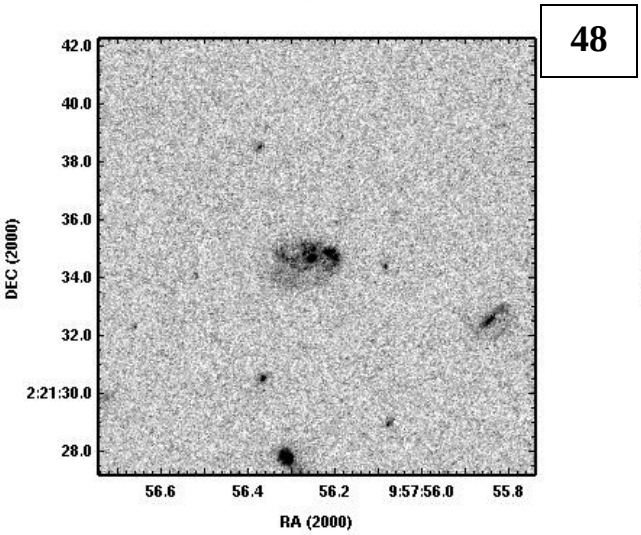
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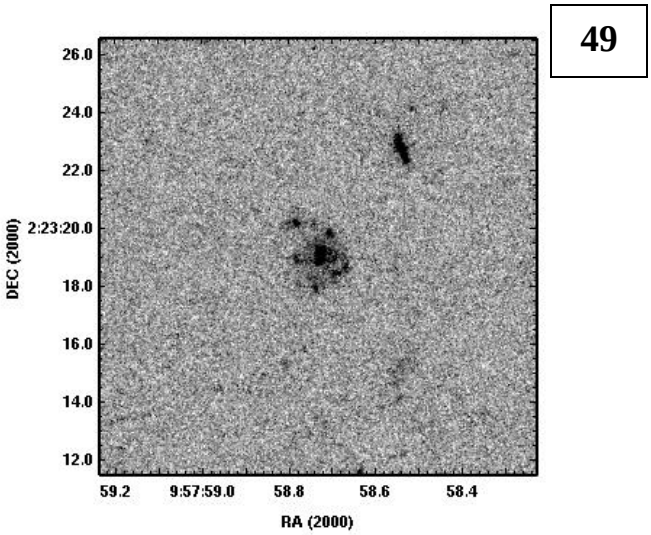
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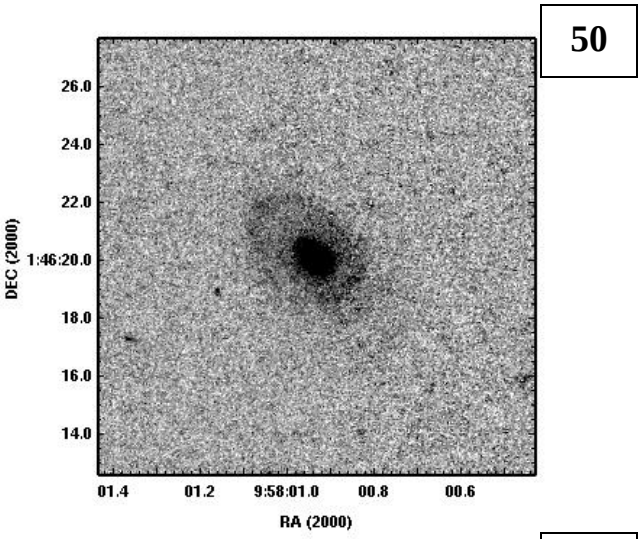
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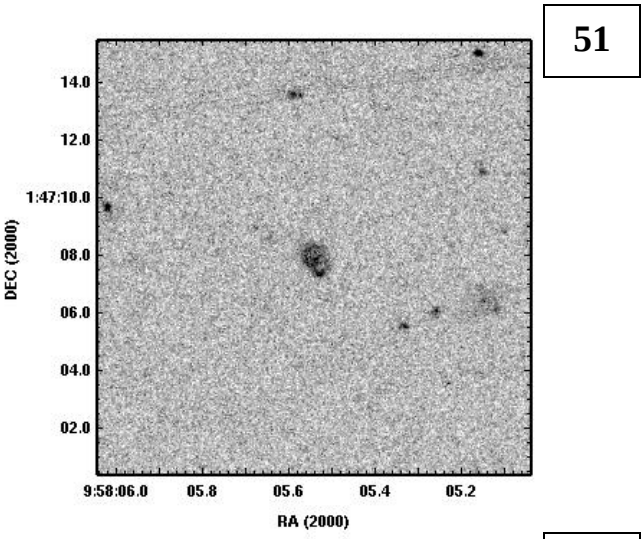
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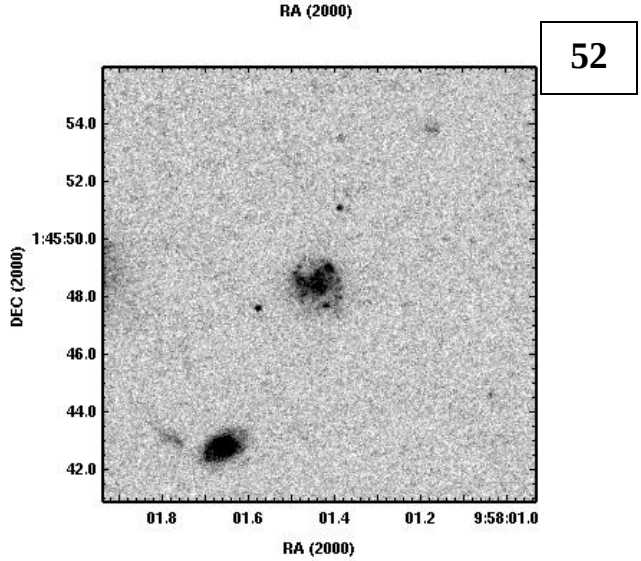
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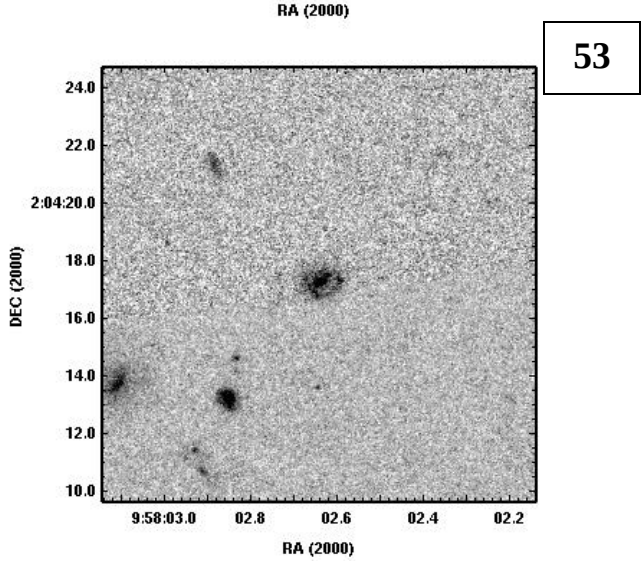
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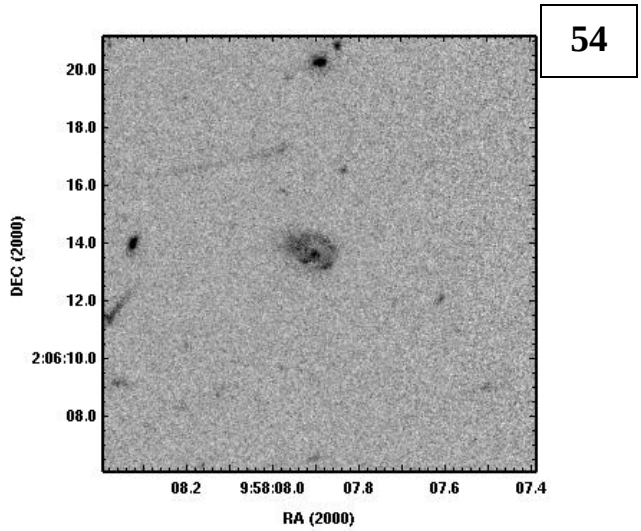
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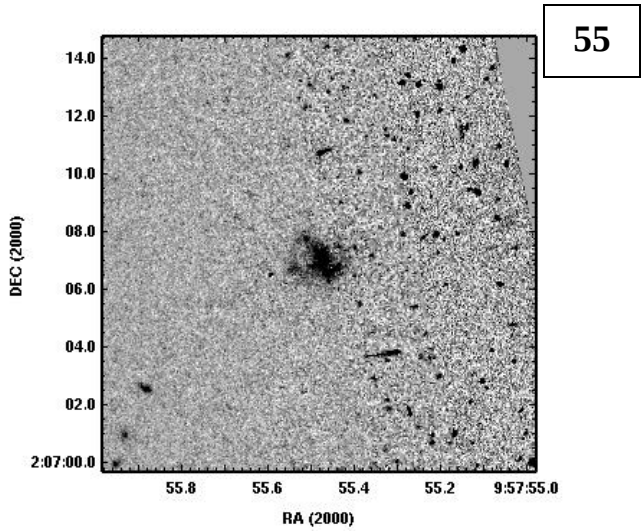
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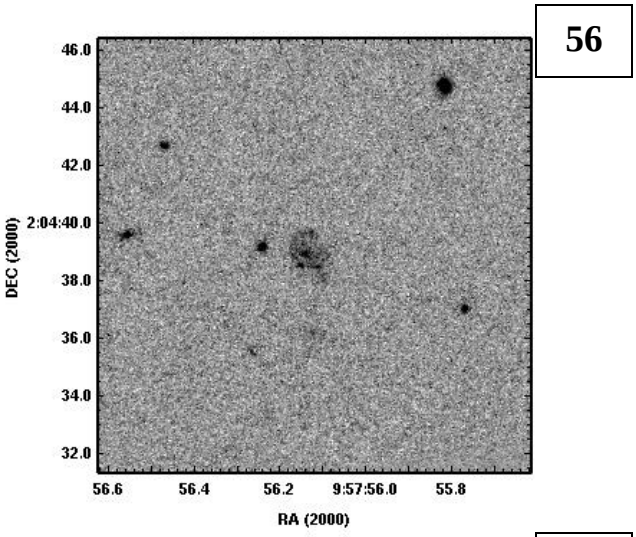
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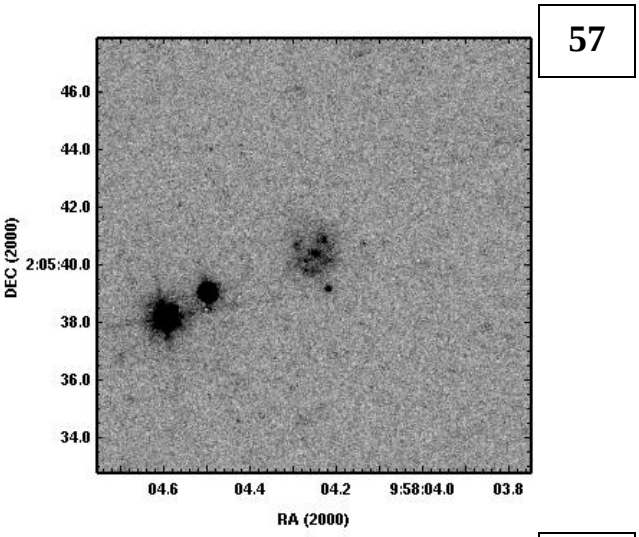
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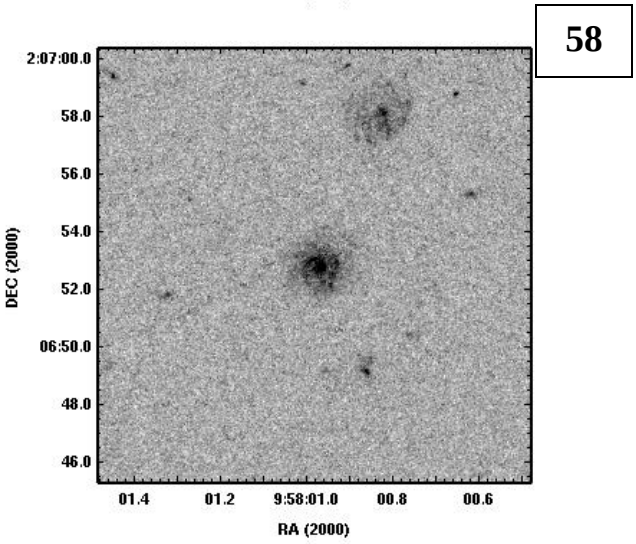
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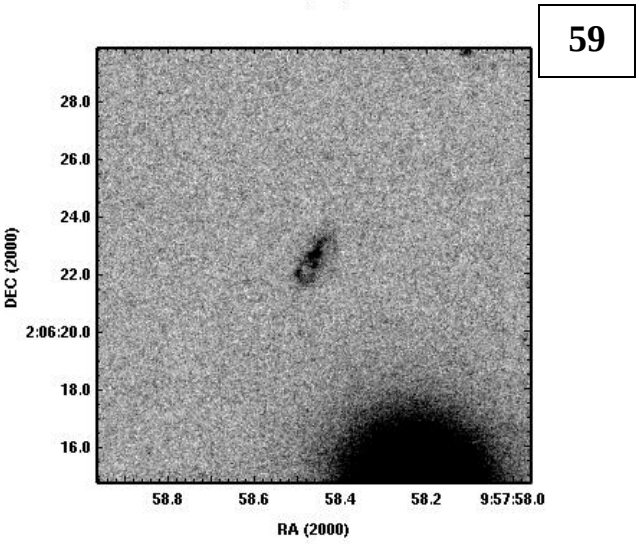
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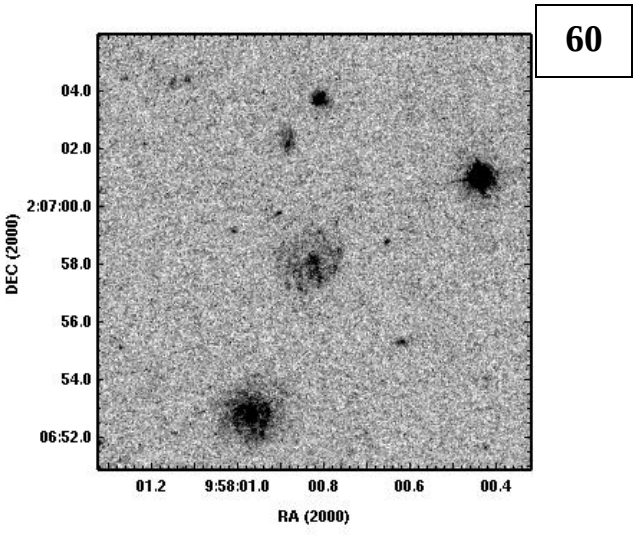
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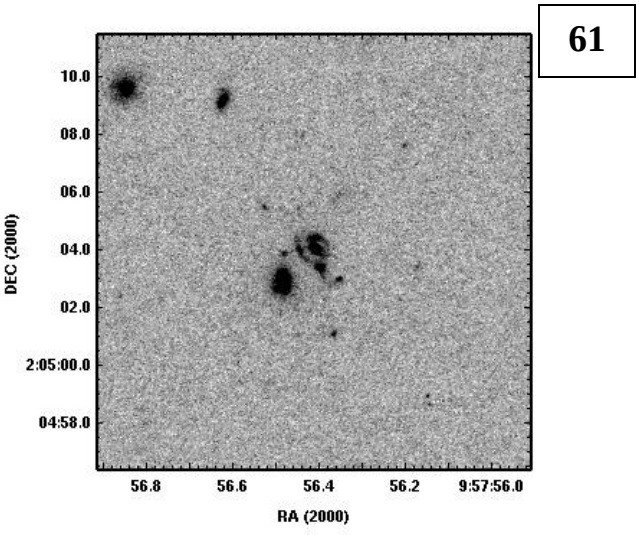
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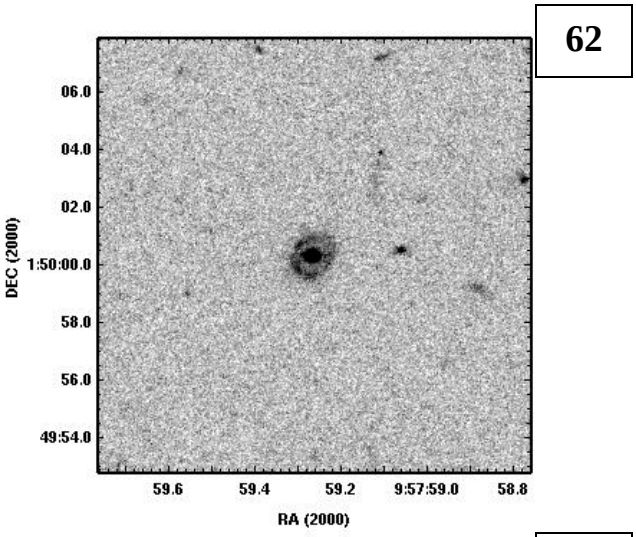
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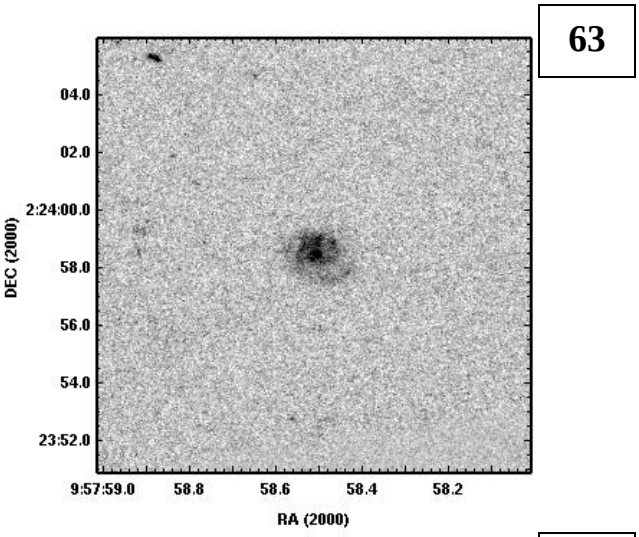
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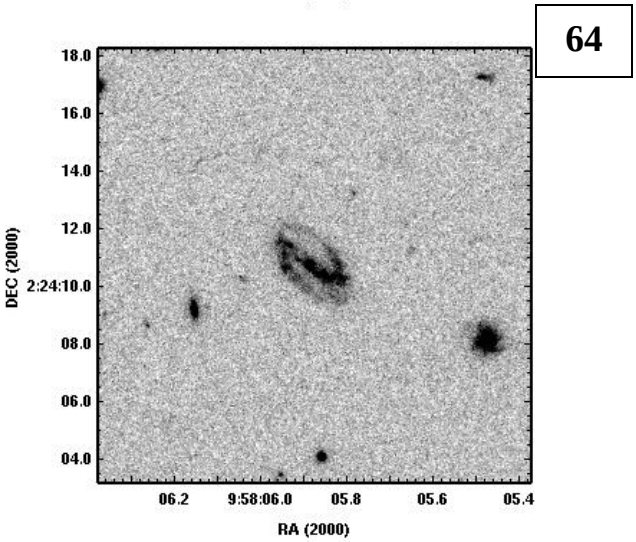
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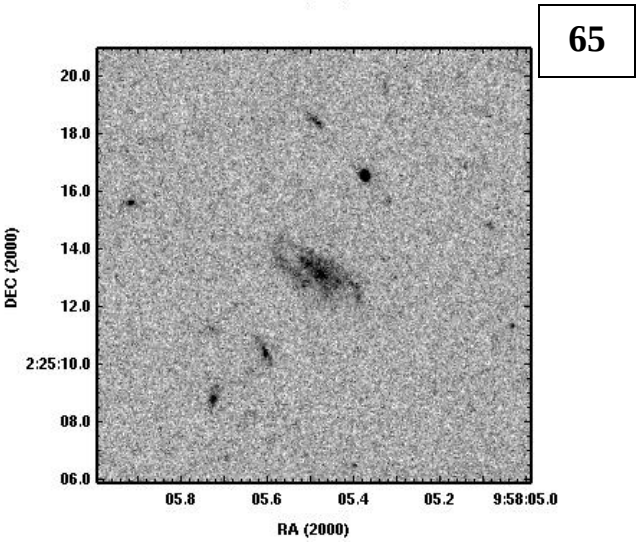
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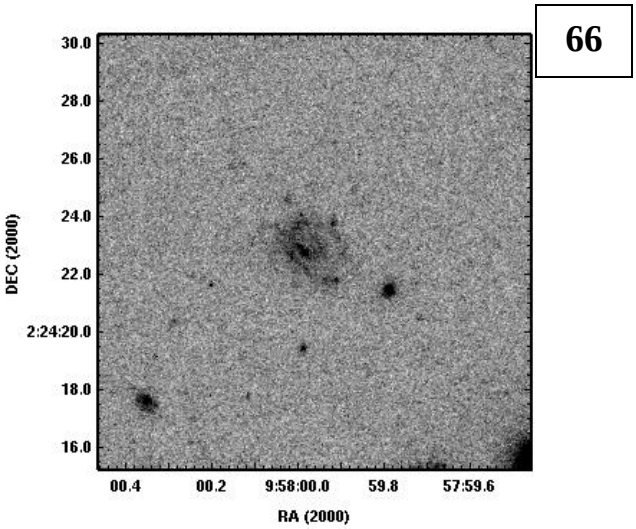
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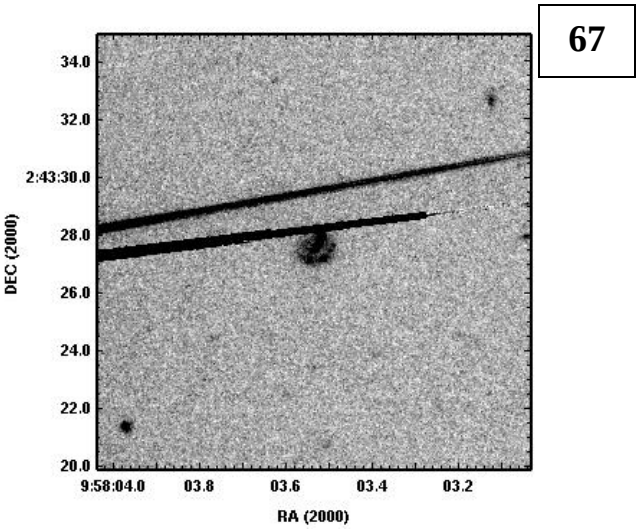
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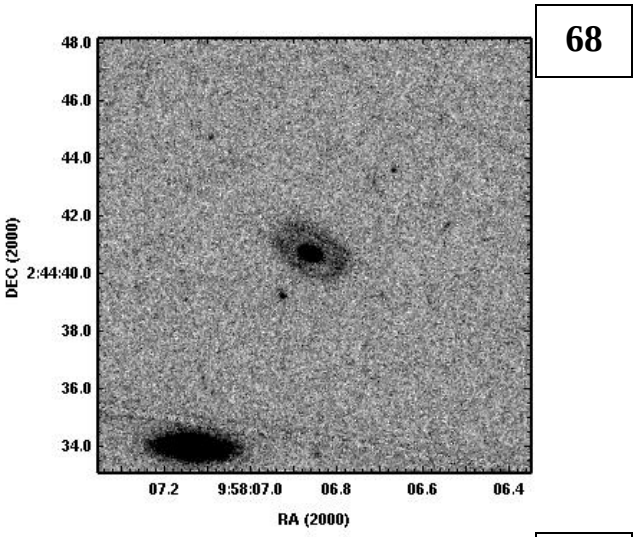
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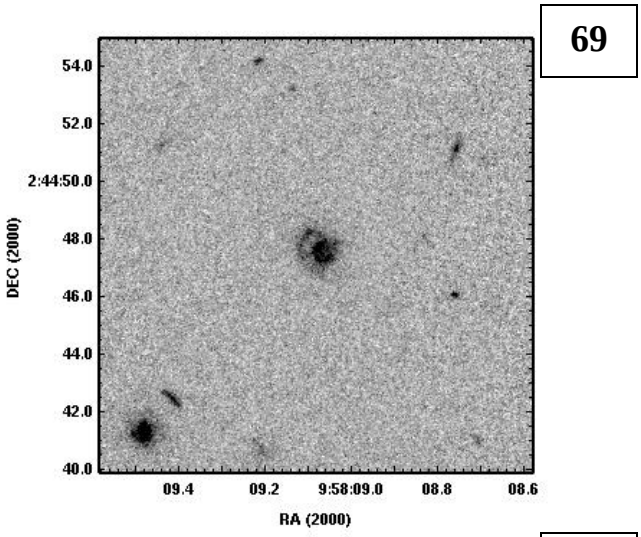
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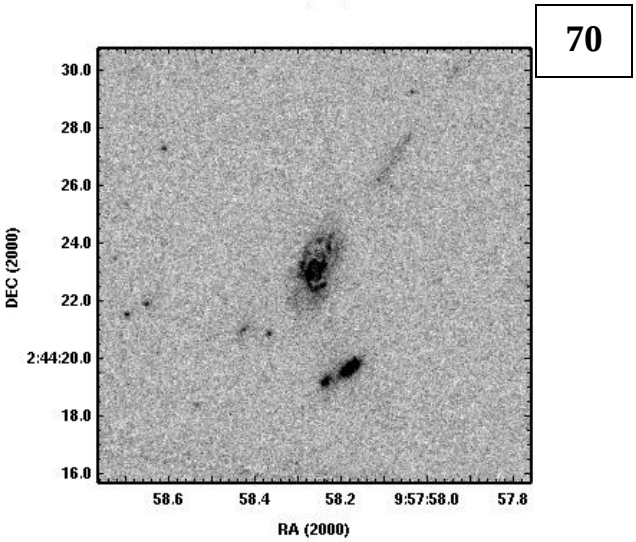
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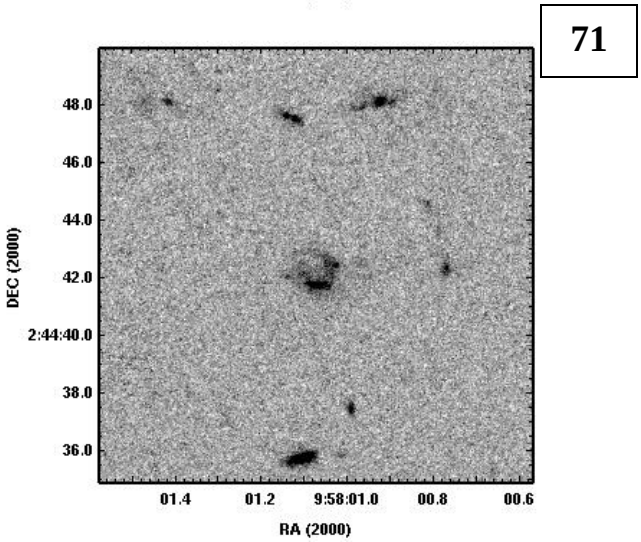
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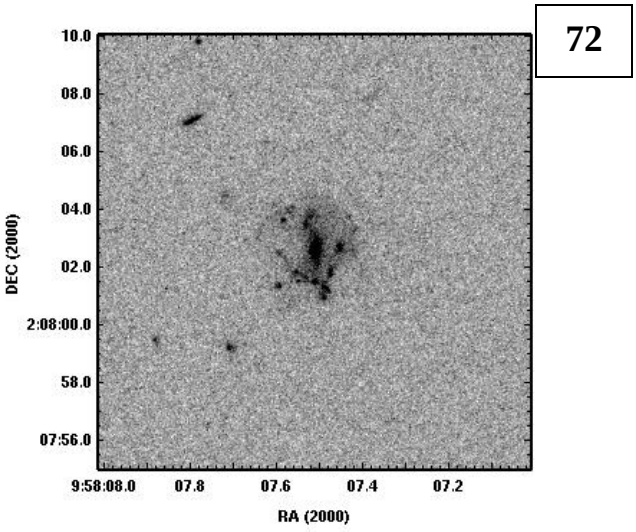
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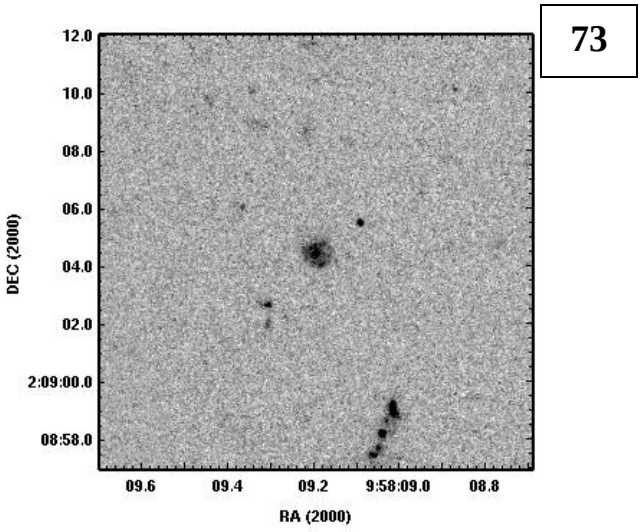
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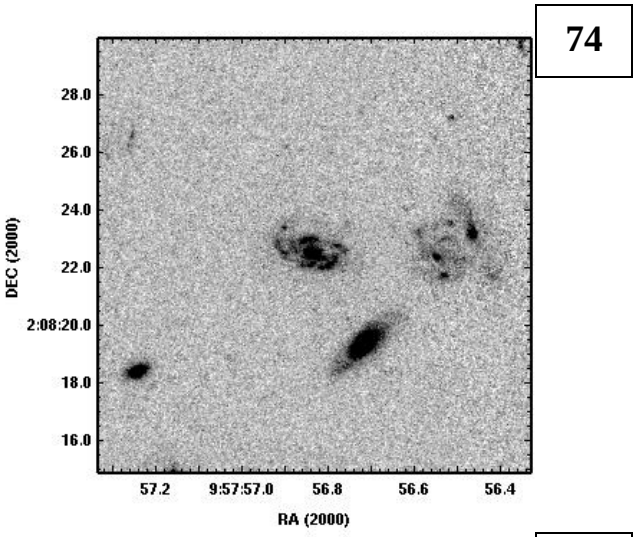
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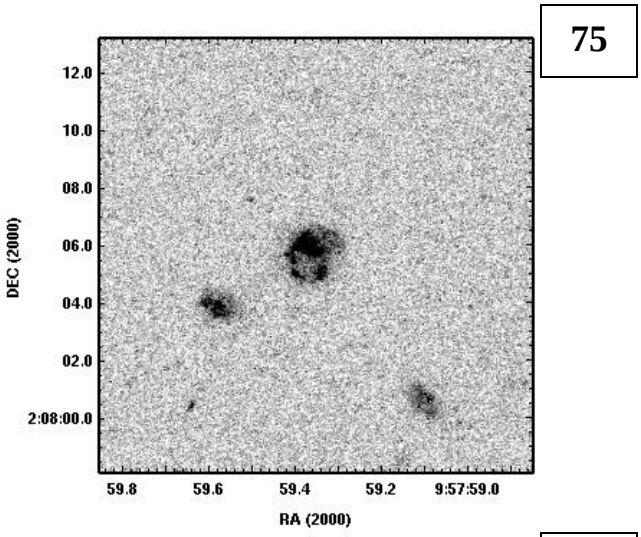
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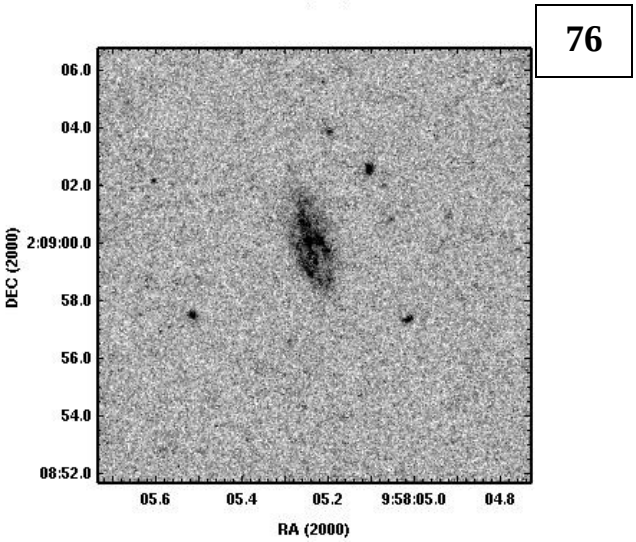
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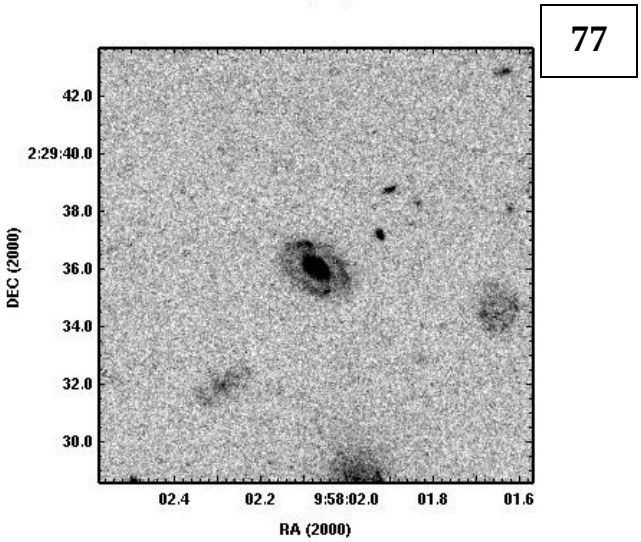
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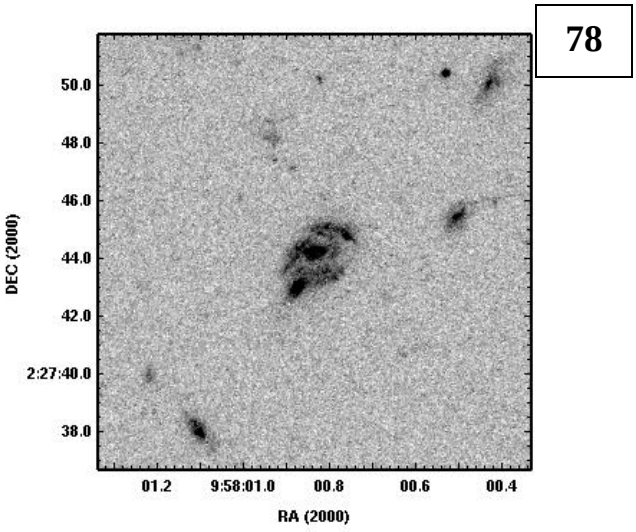
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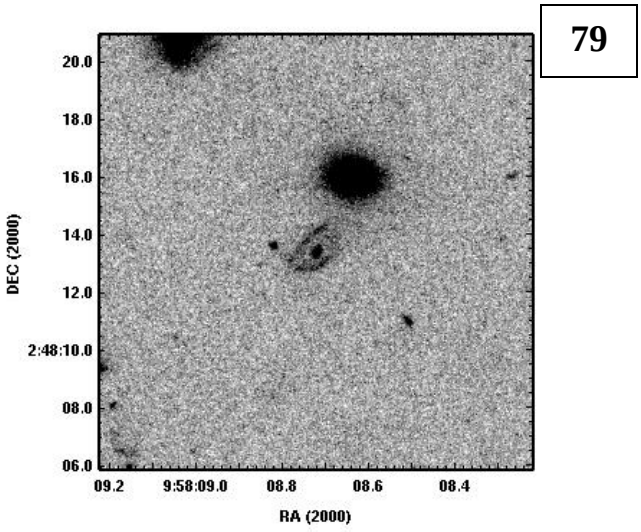
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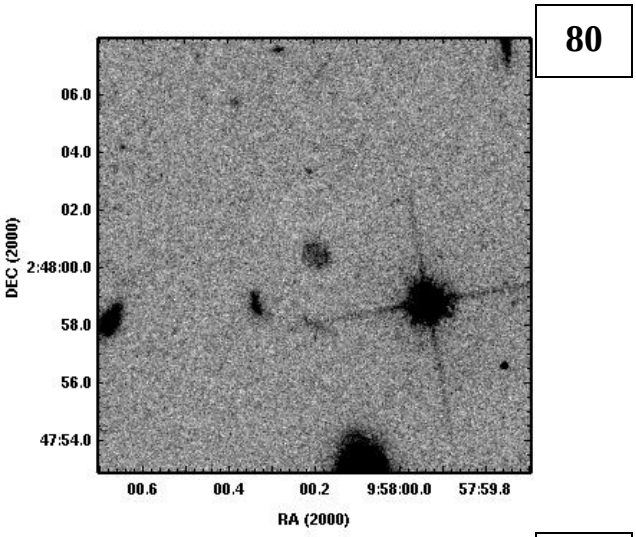
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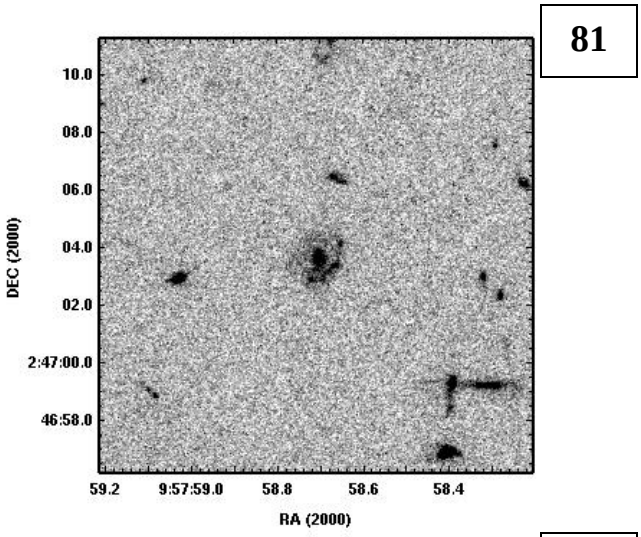
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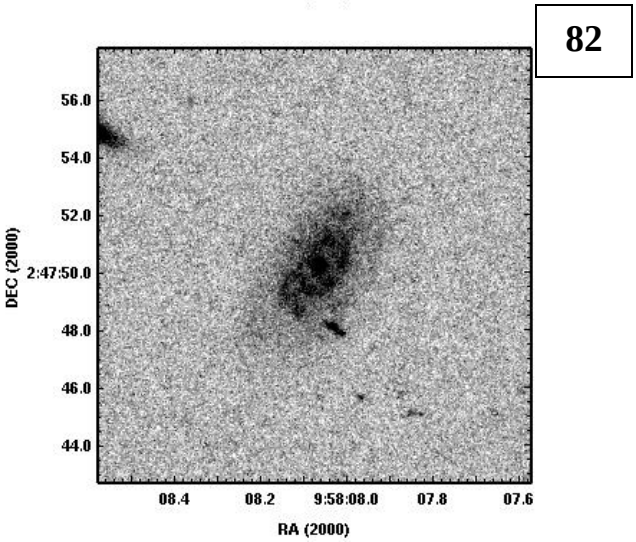
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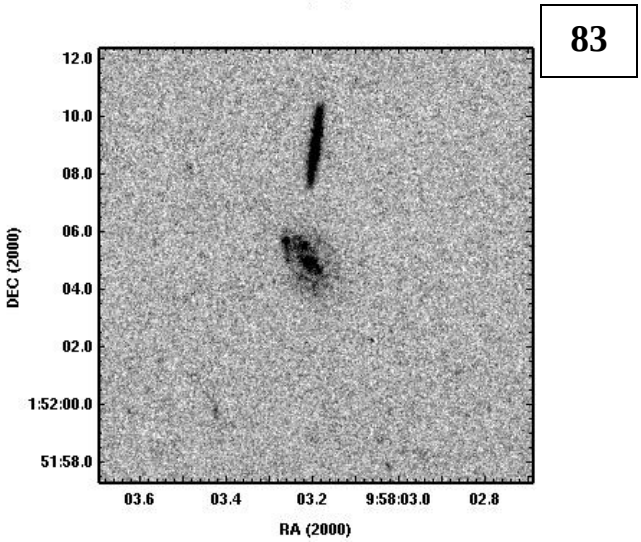
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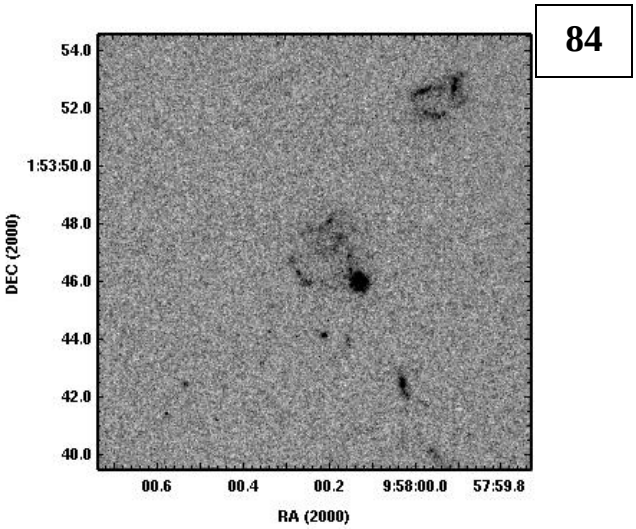
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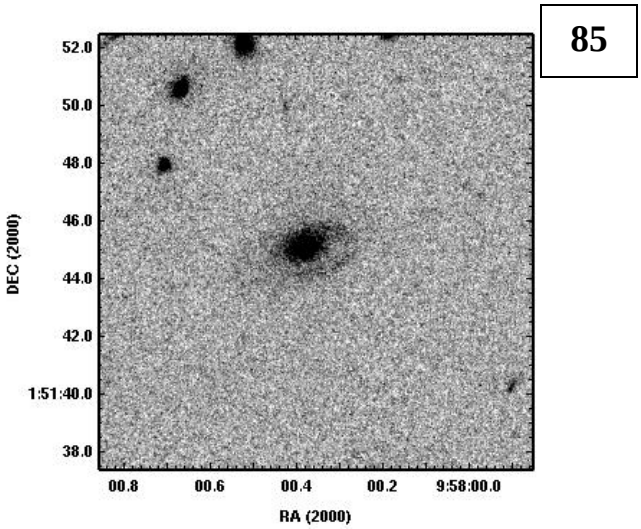
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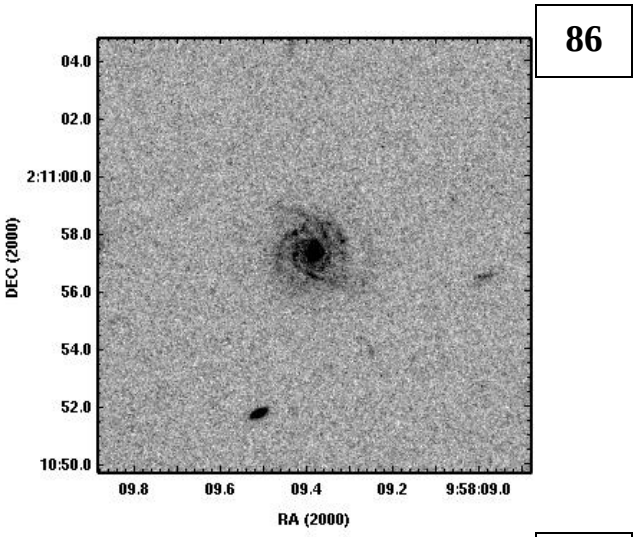
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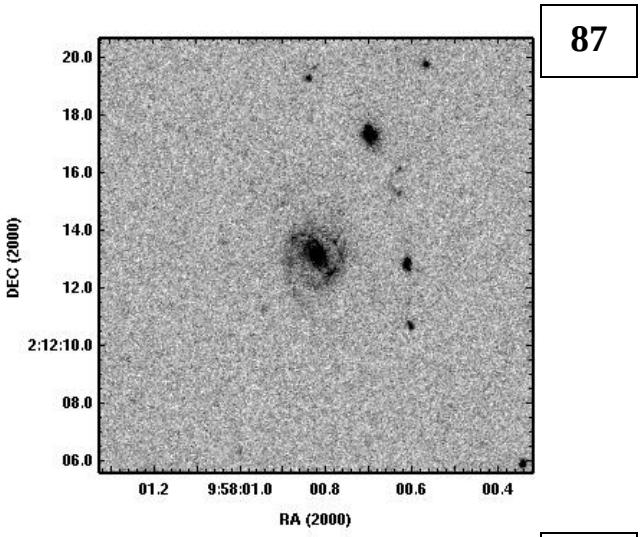
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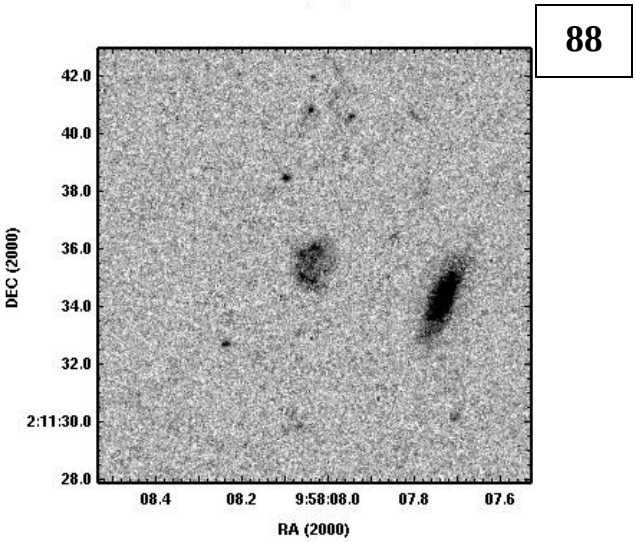
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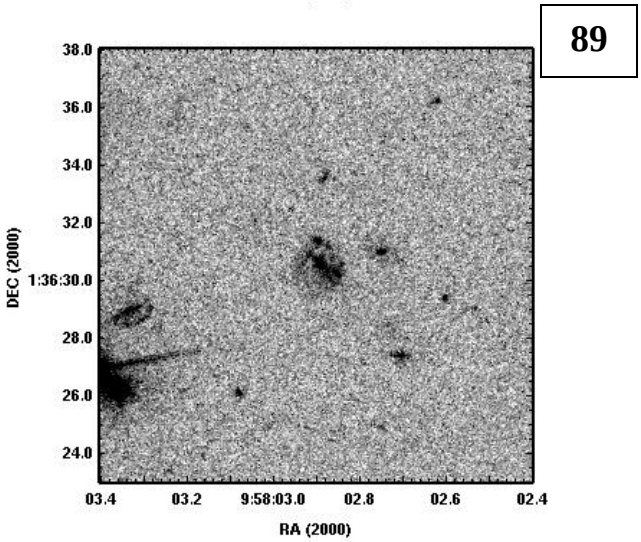
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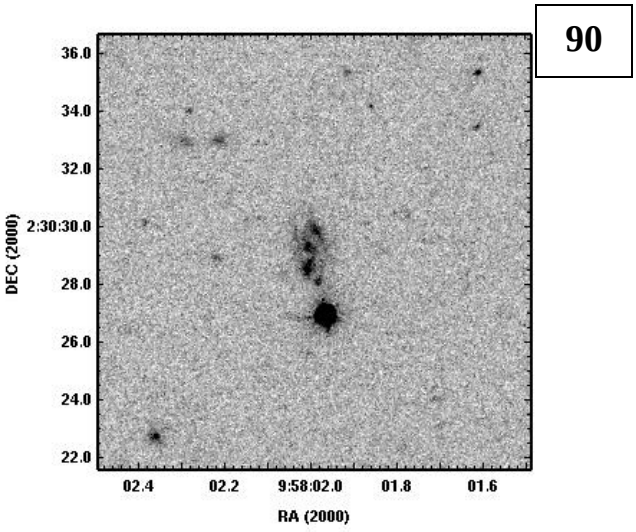
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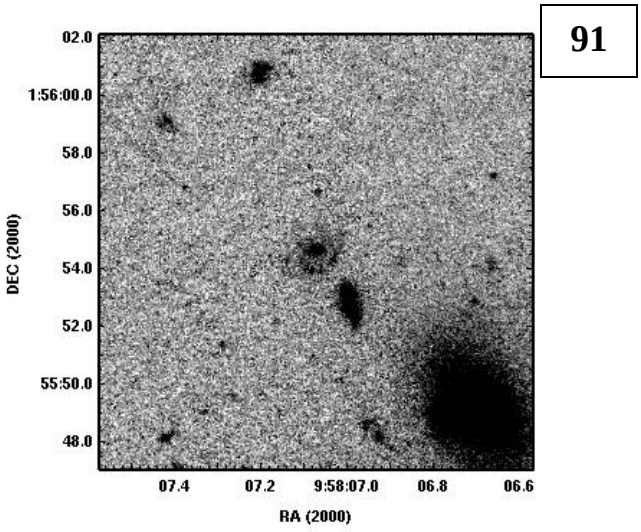
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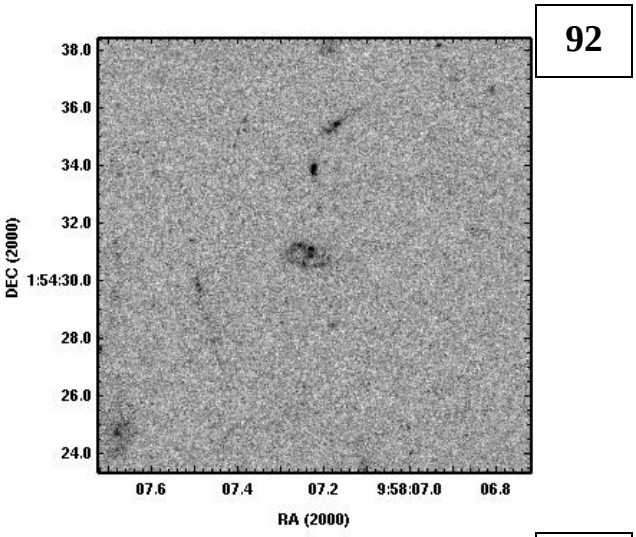
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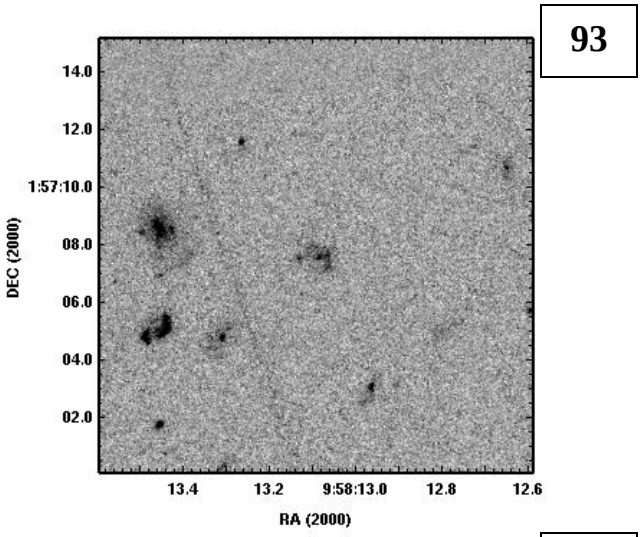
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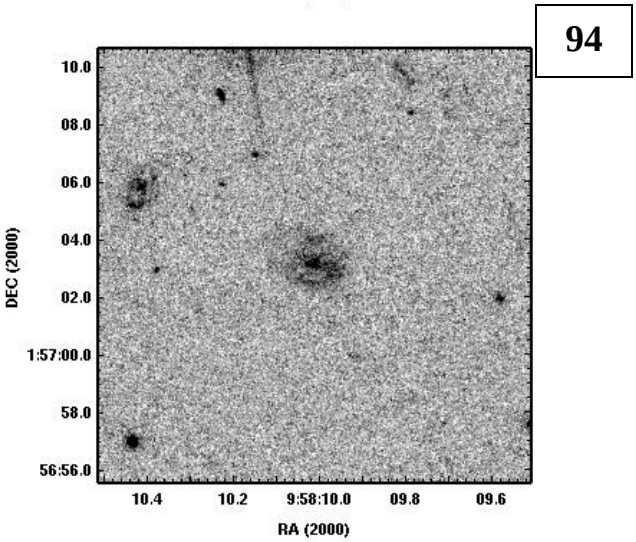
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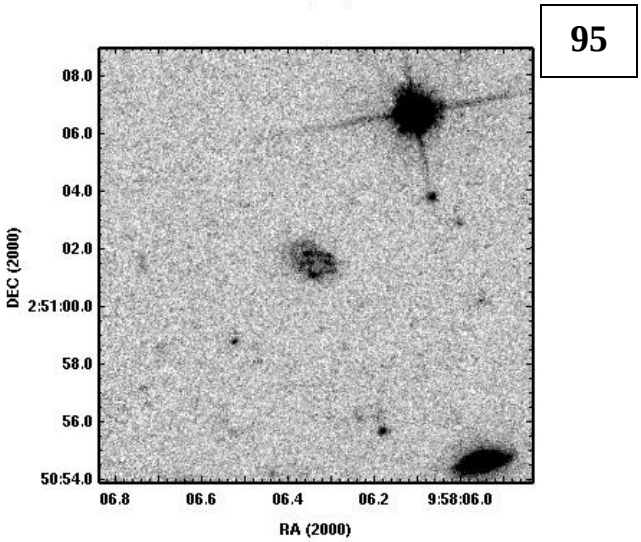
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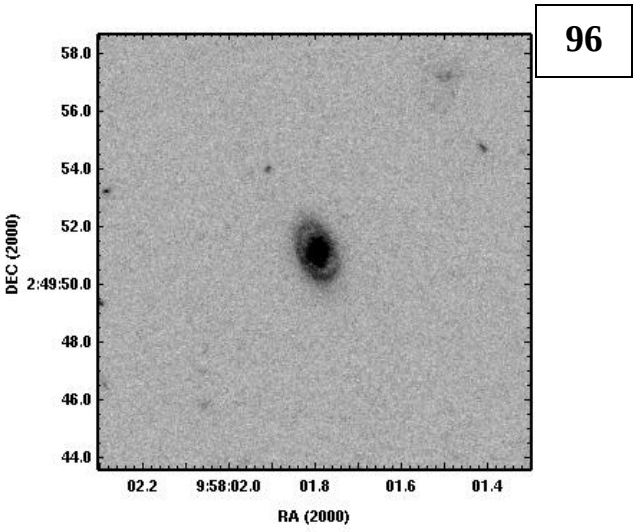
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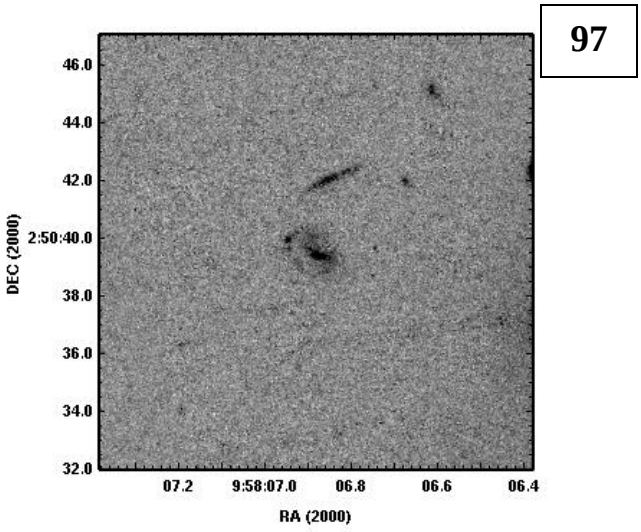
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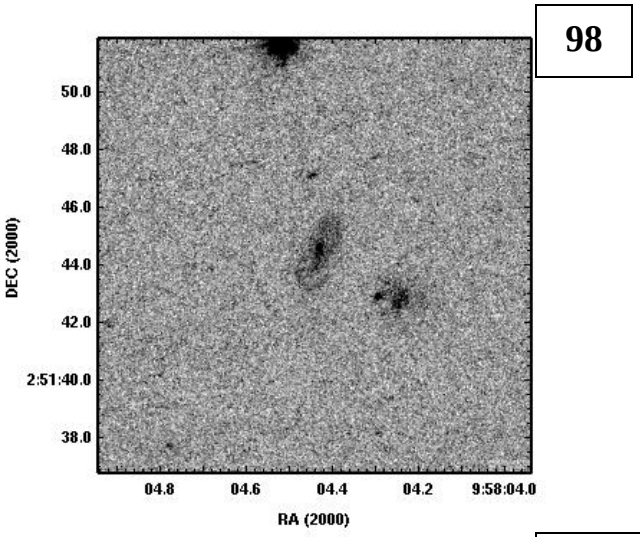
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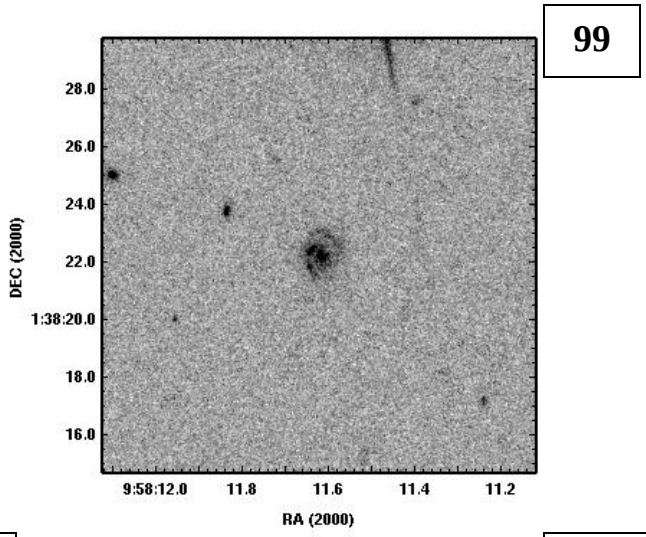
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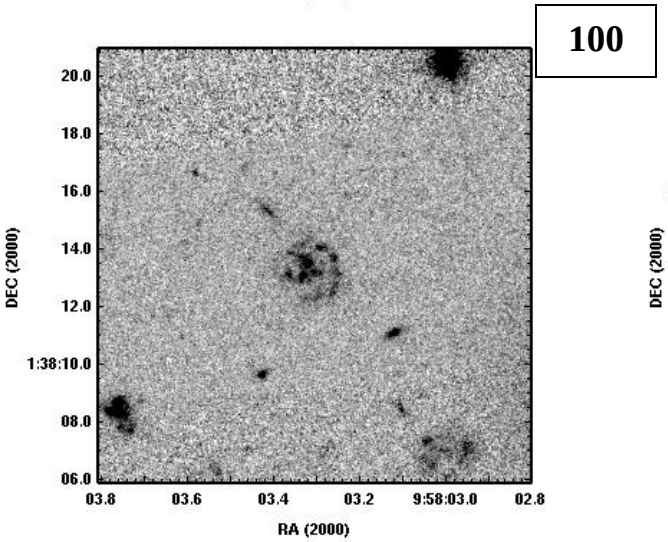
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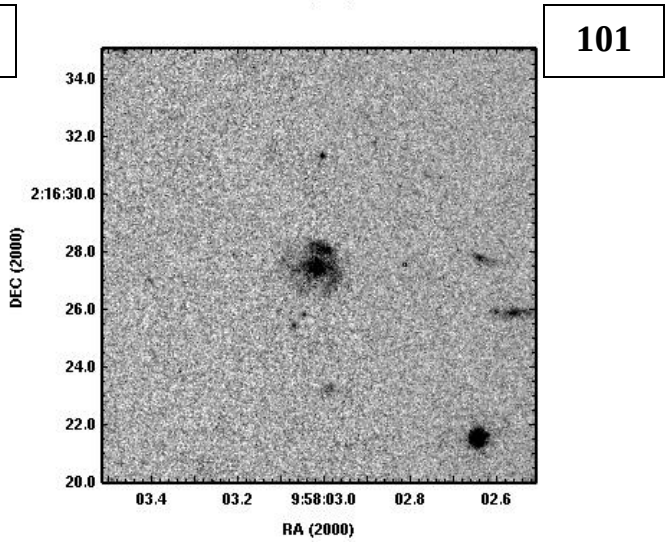
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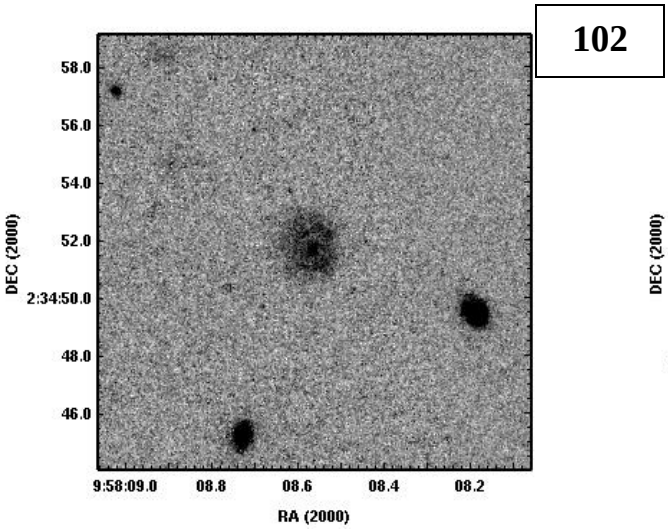
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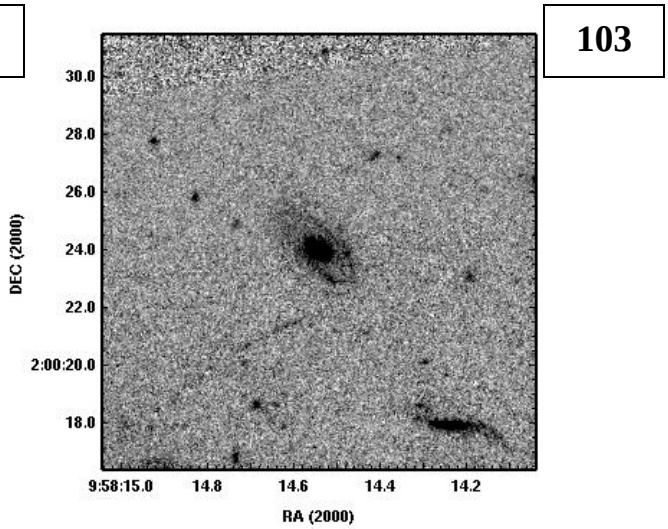
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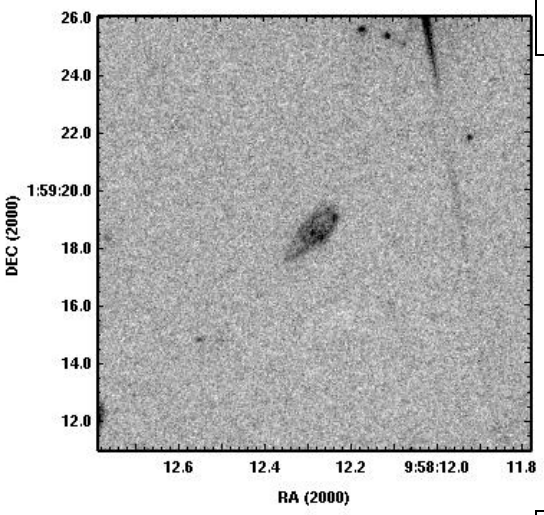
104



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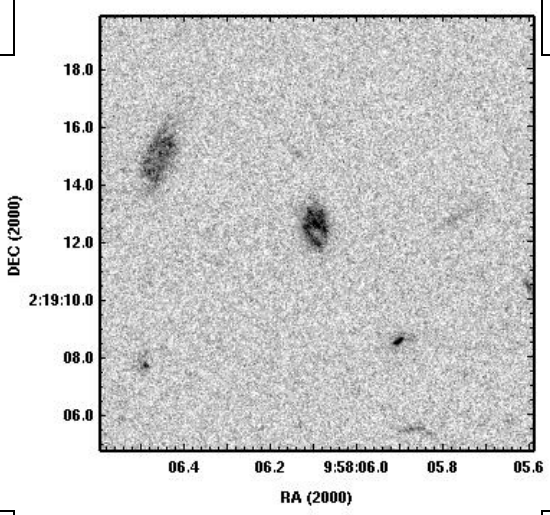

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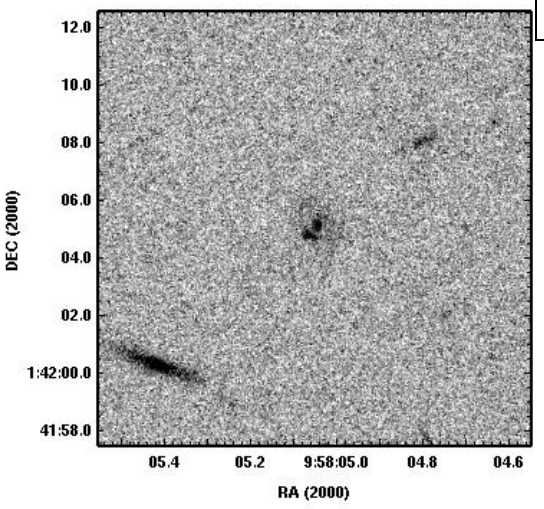
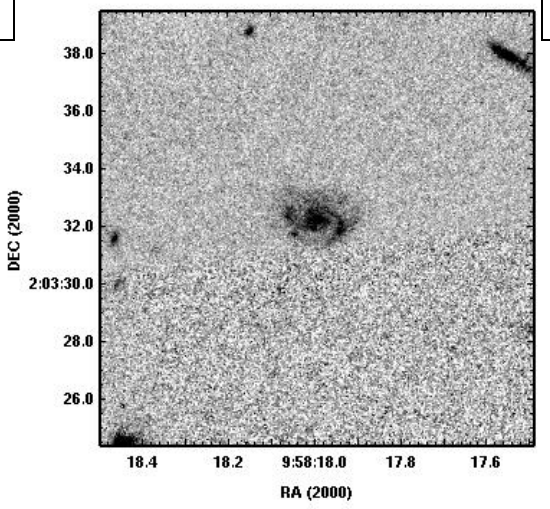


107



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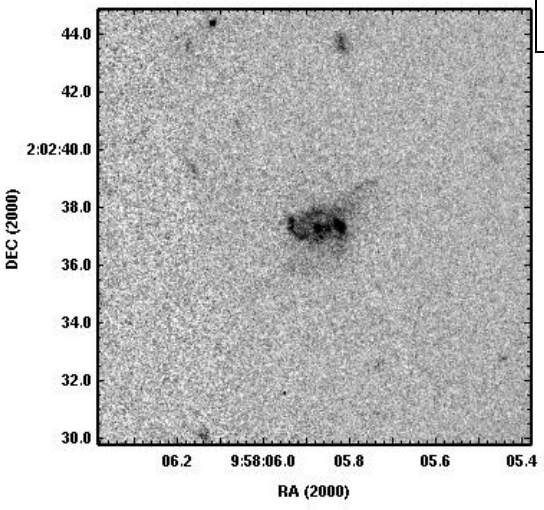

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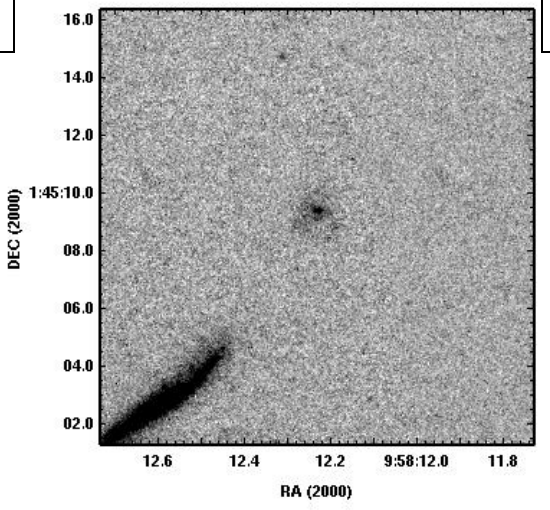

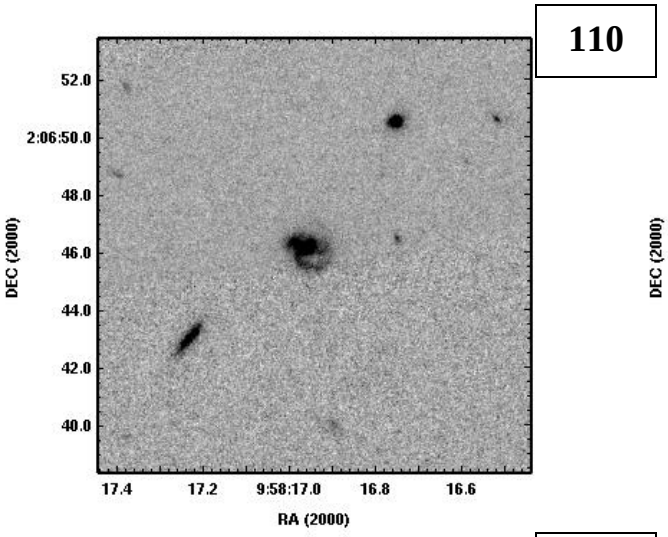
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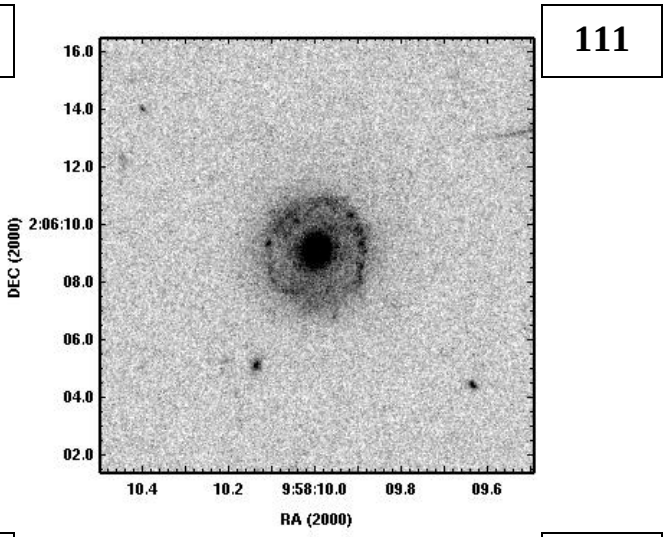
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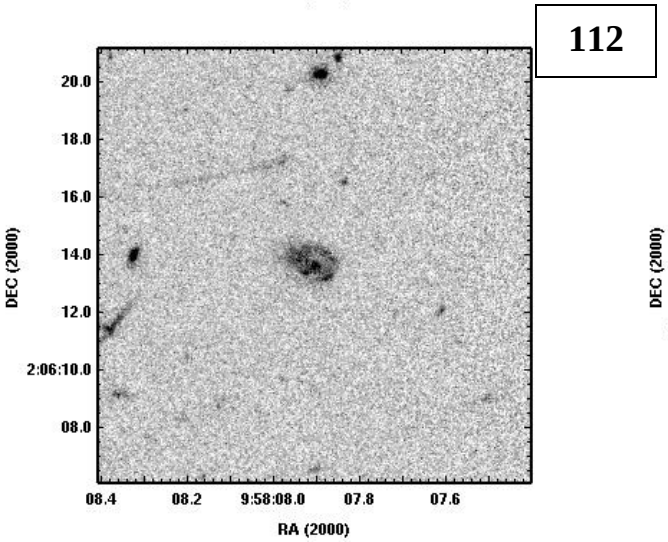
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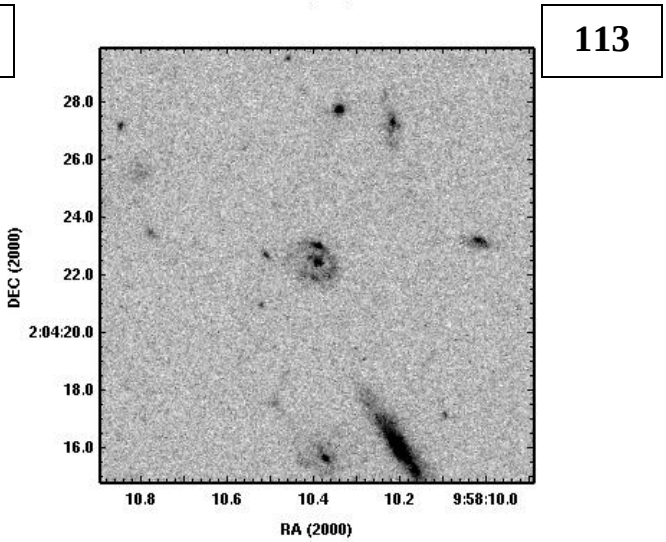
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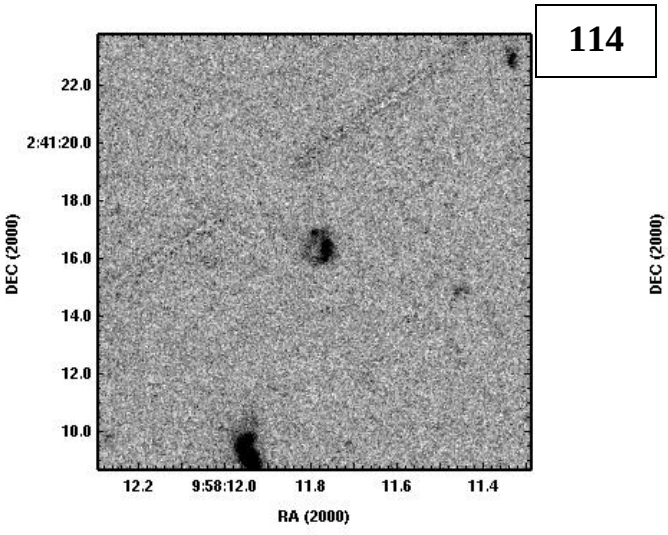
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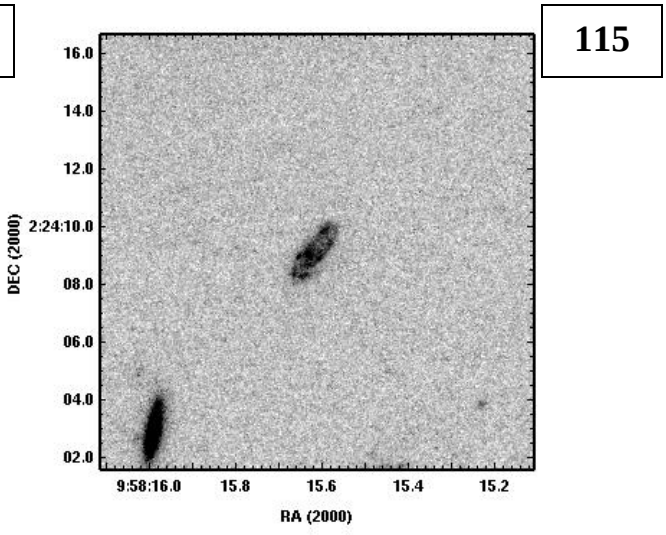
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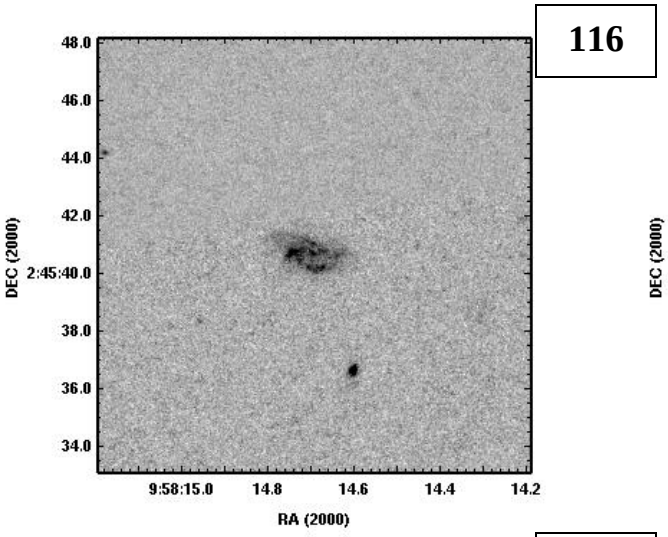
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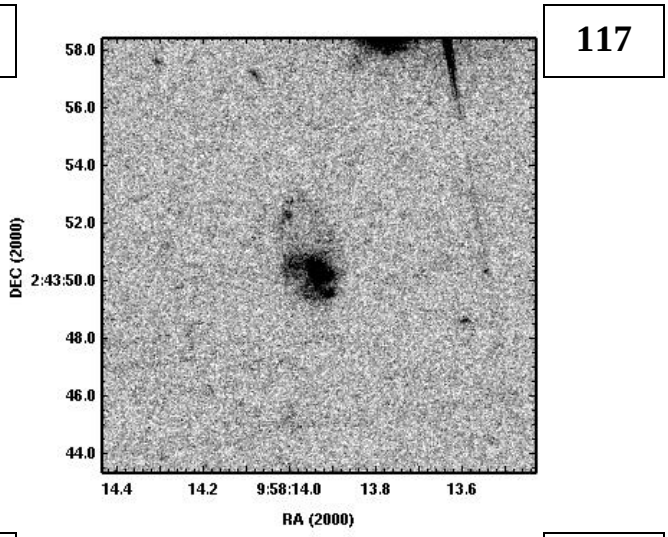
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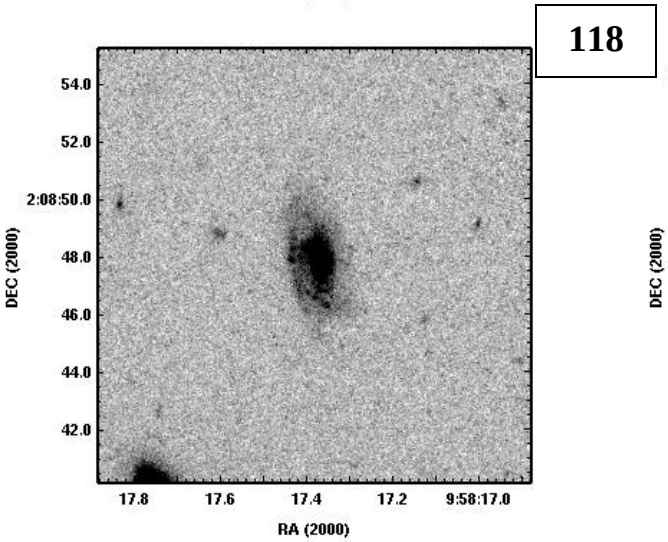
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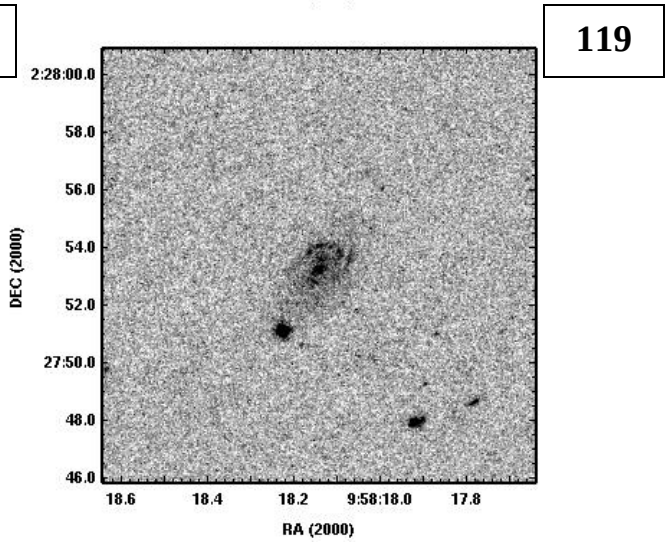
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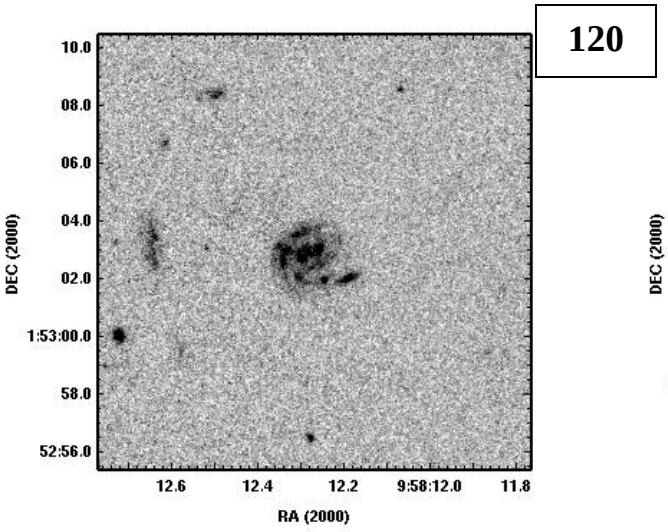
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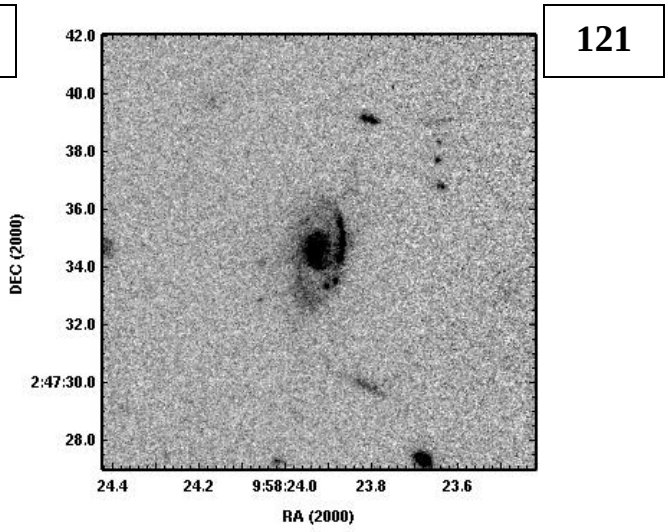
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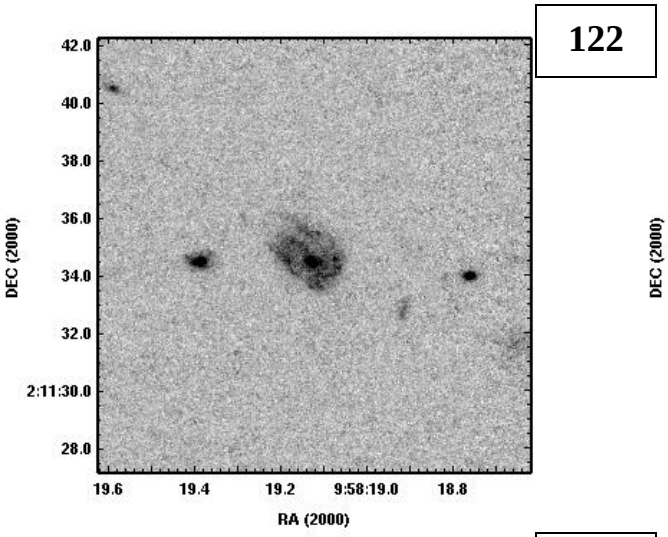
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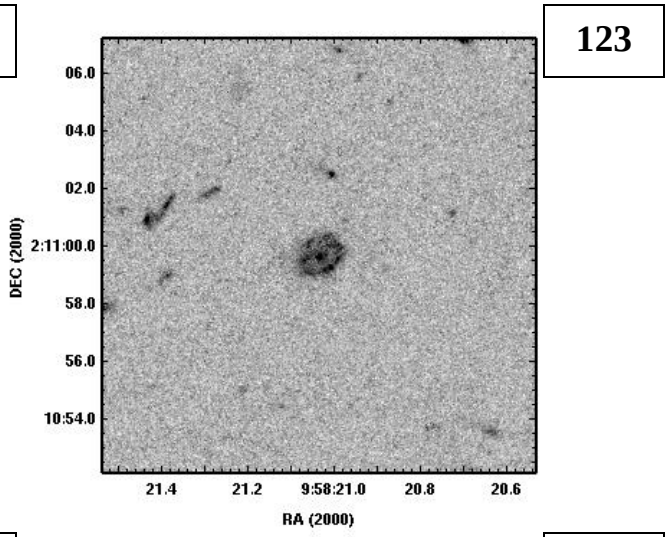
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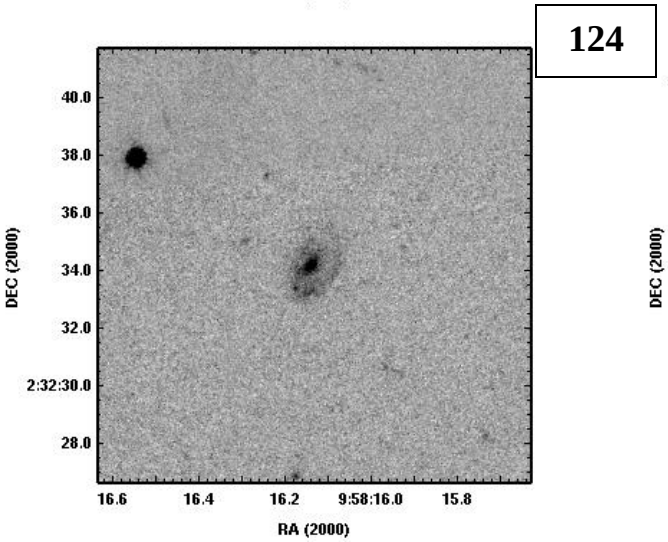
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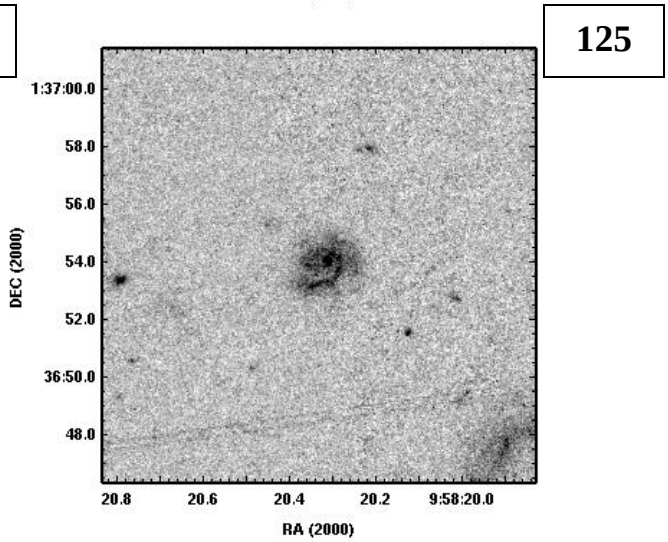
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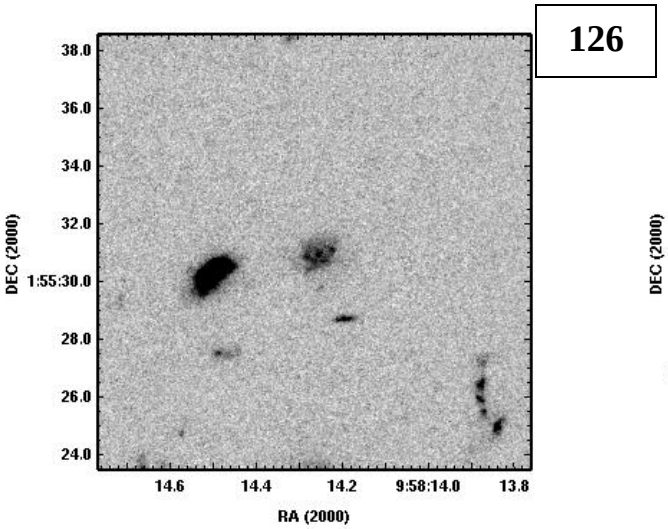
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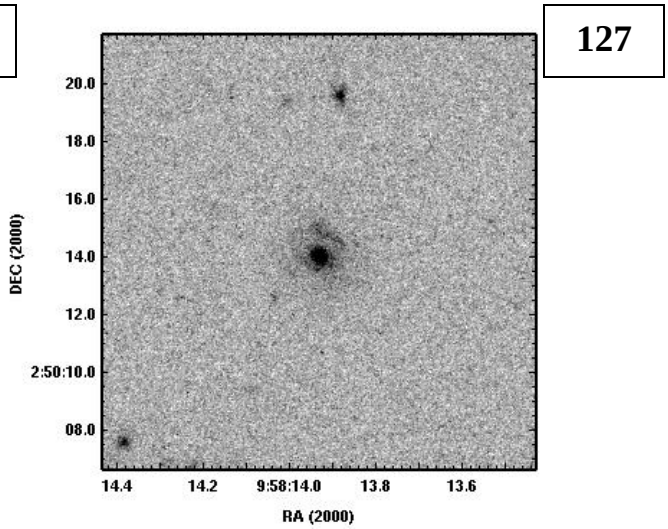
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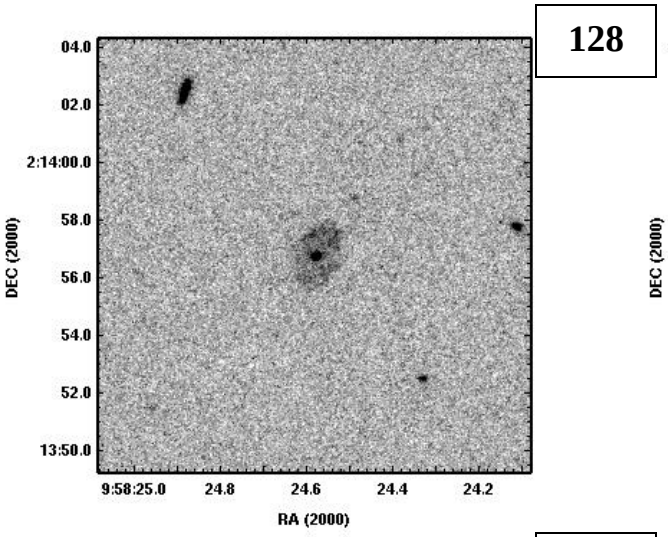
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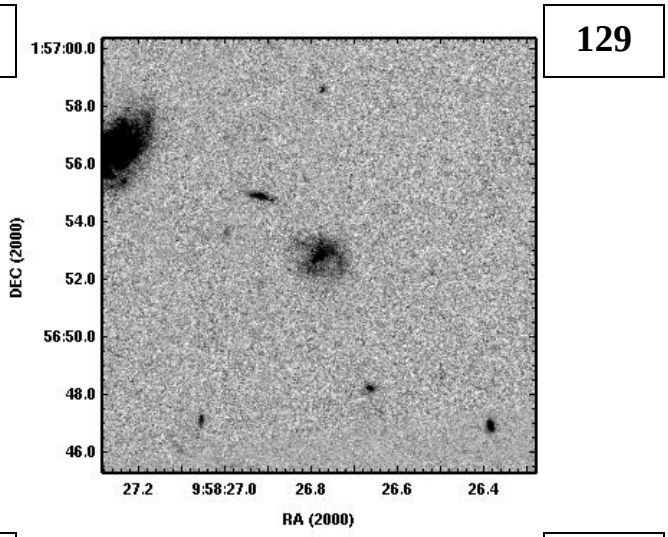
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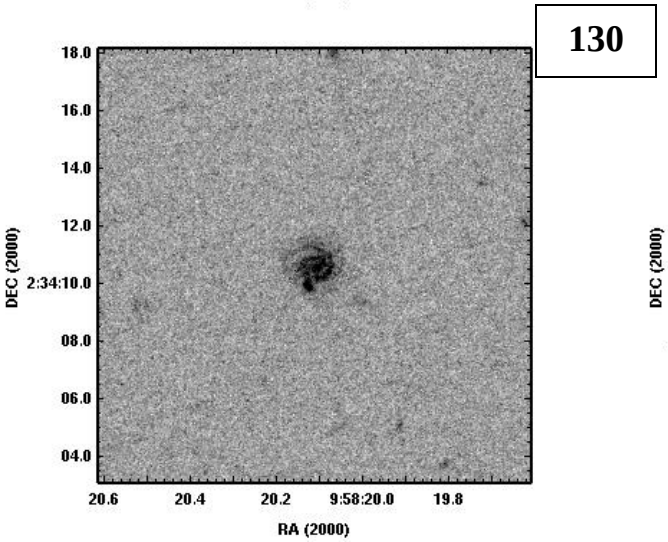
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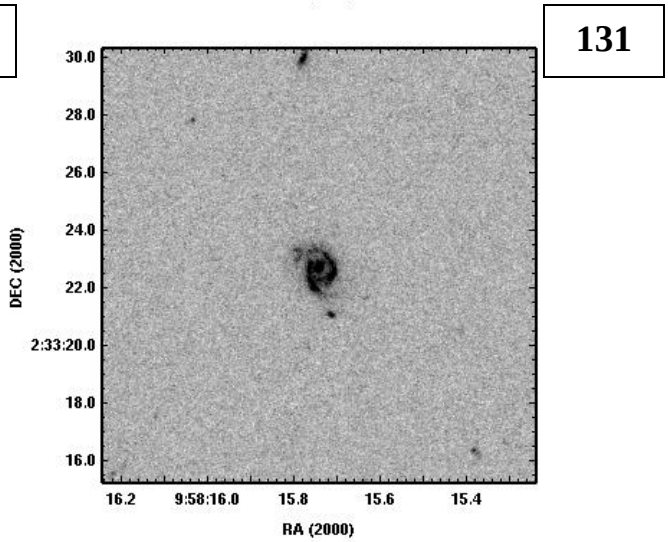
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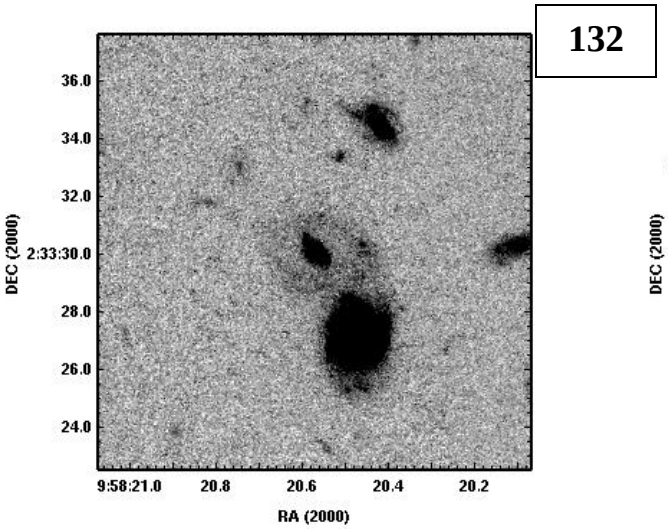
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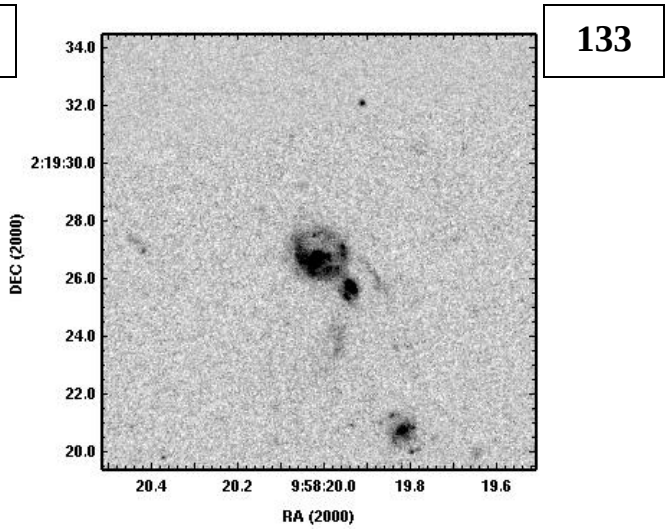
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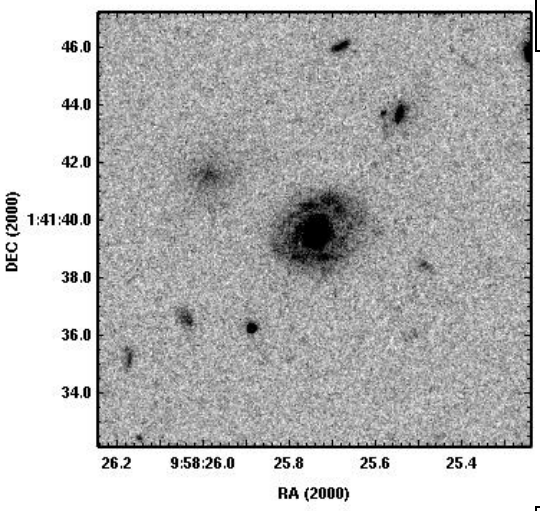
RA (2000)

134



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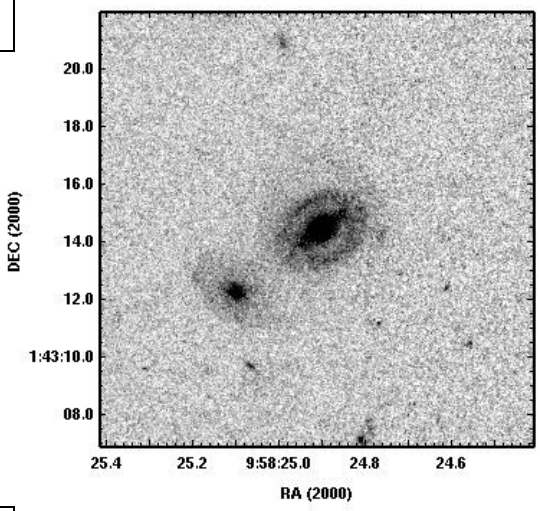

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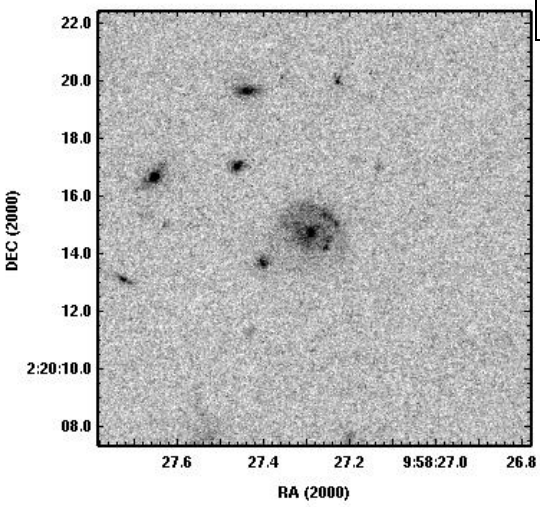
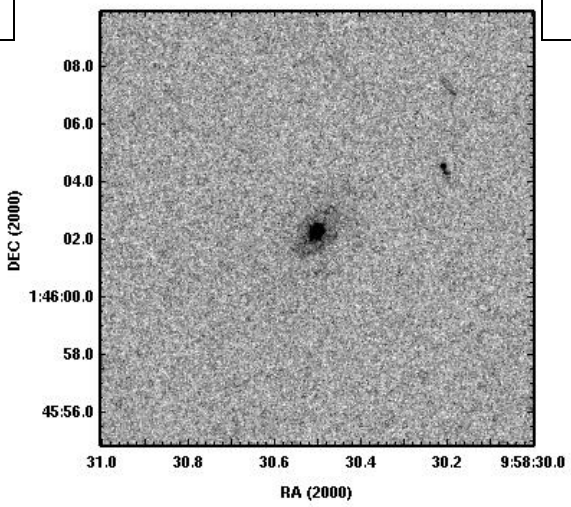


137



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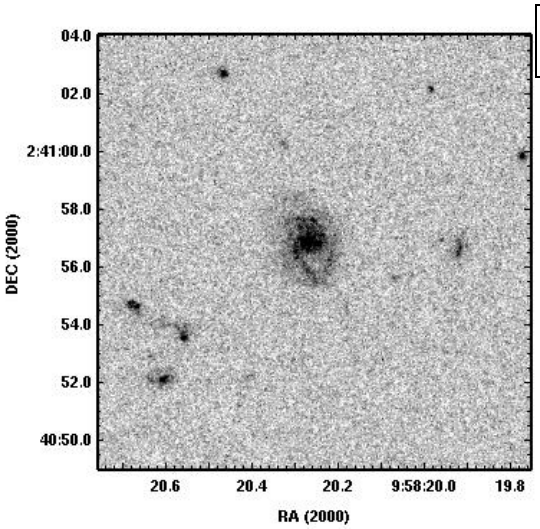

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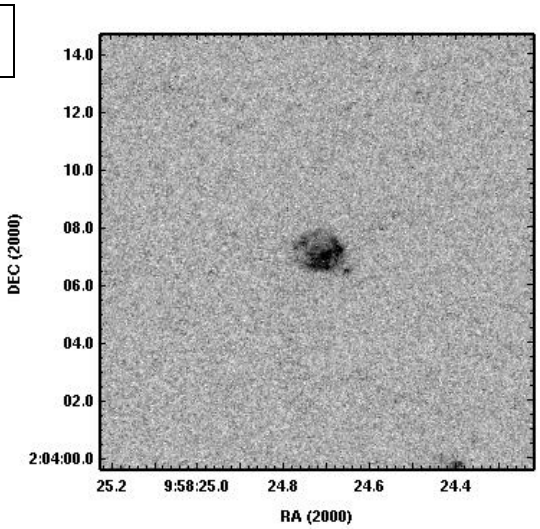

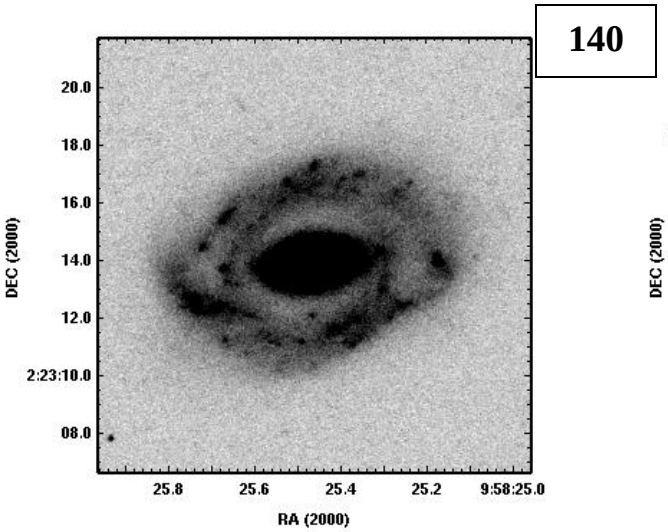
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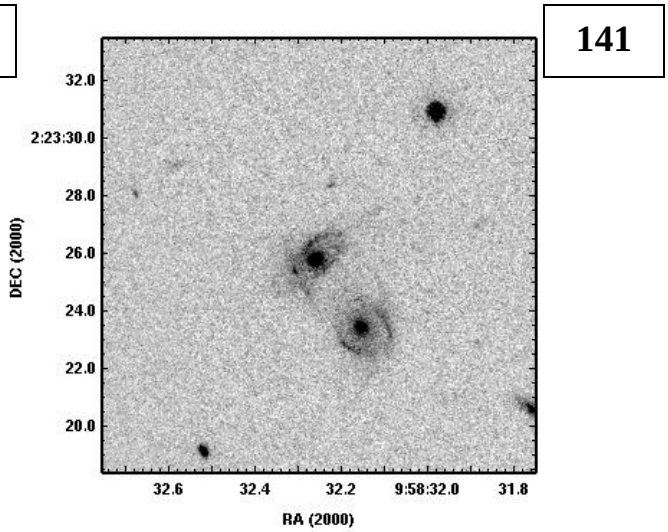
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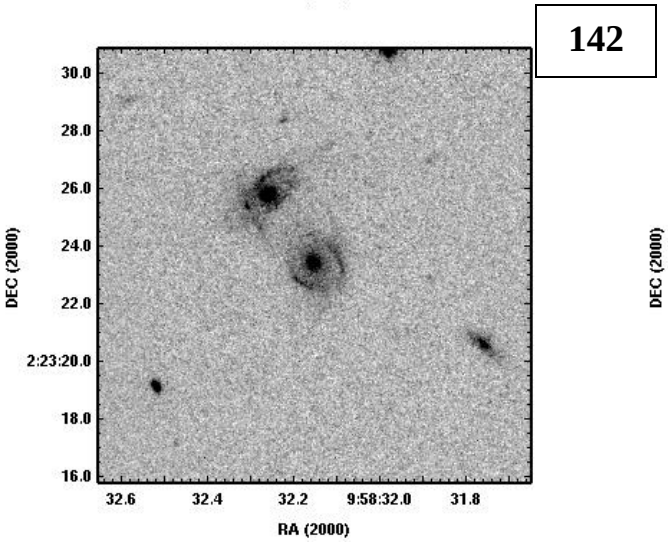
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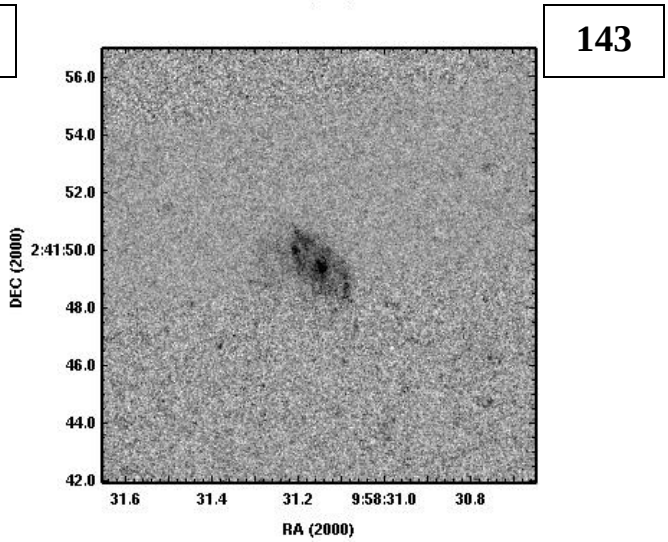
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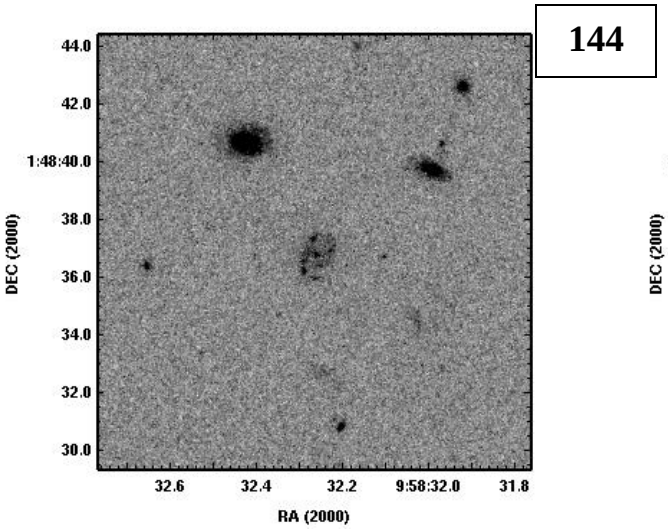
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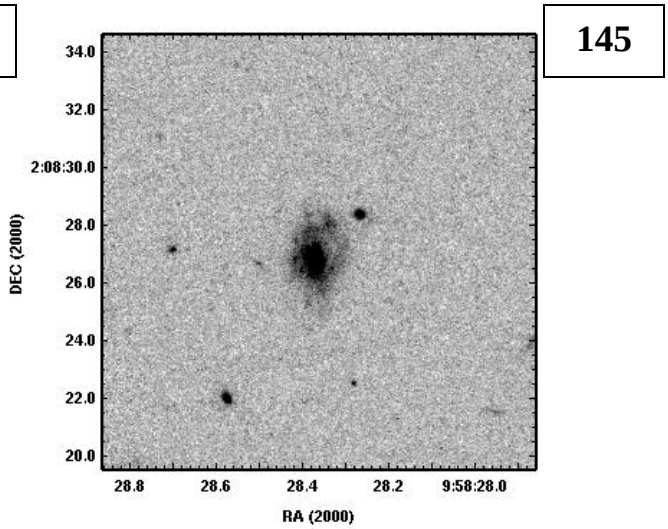
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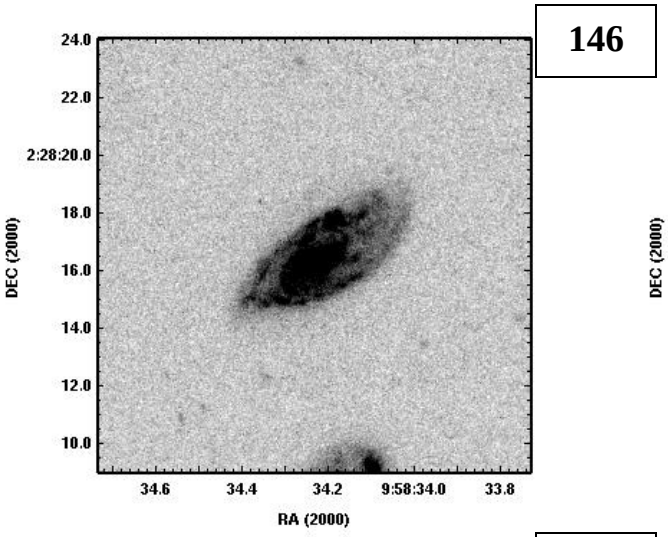
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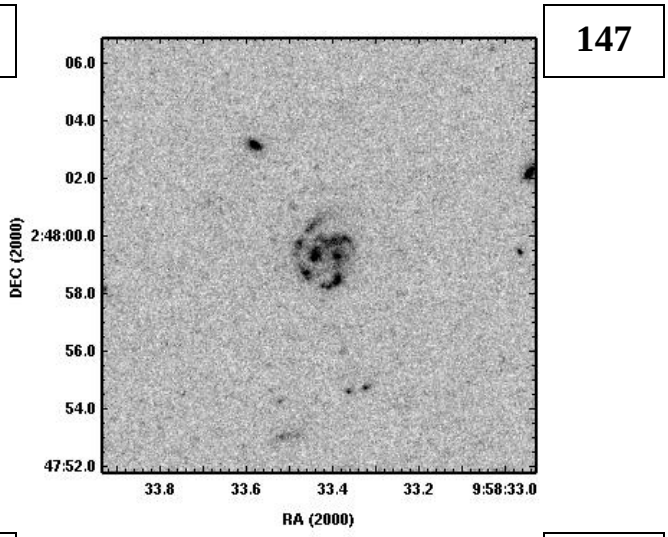
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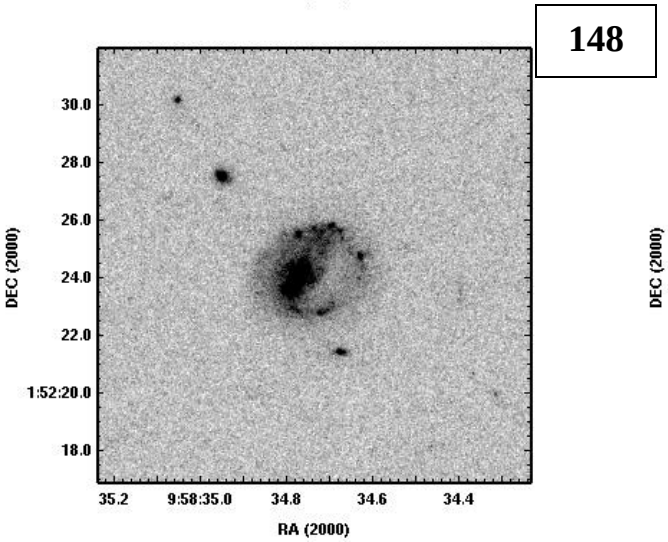
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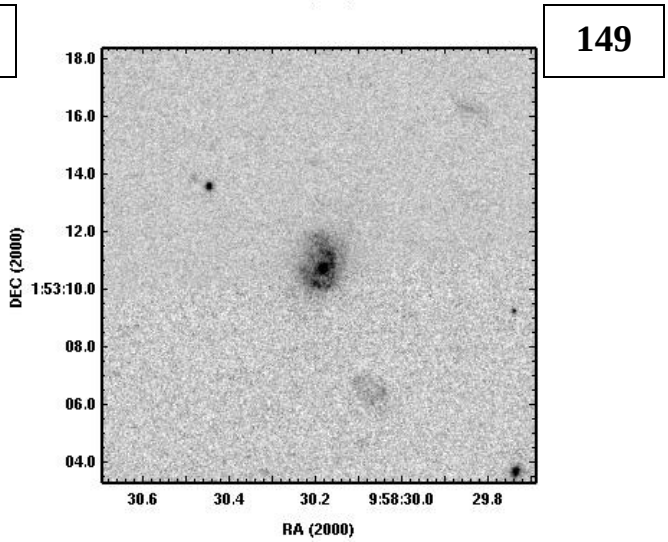
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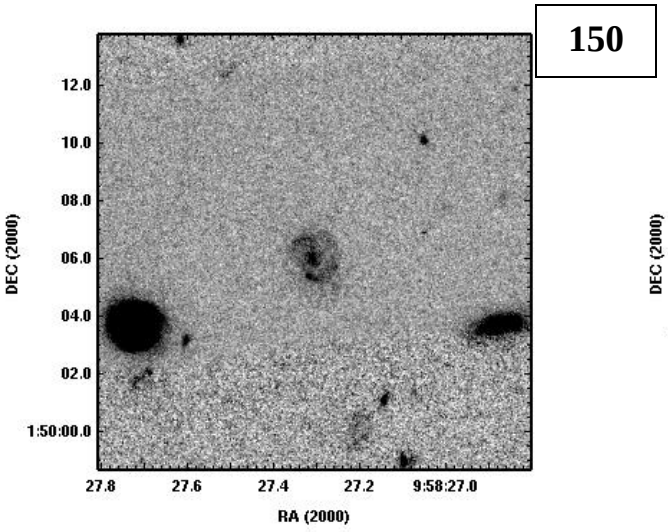
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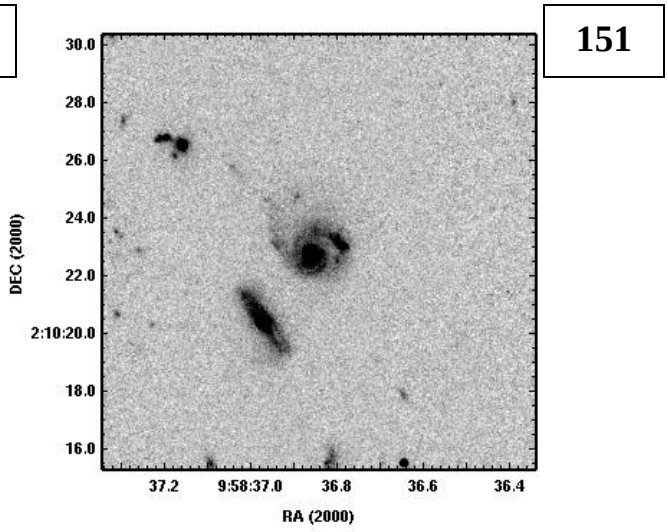
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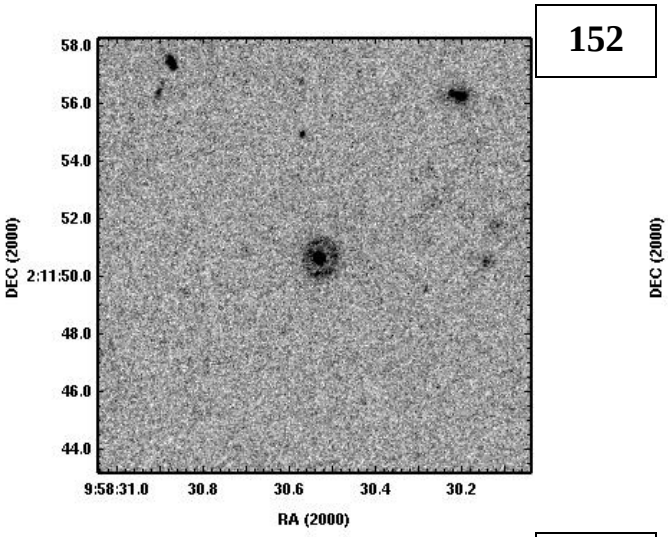
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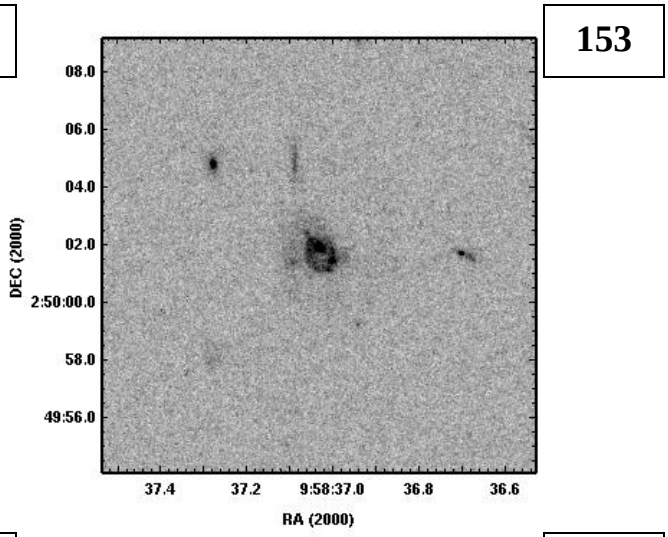
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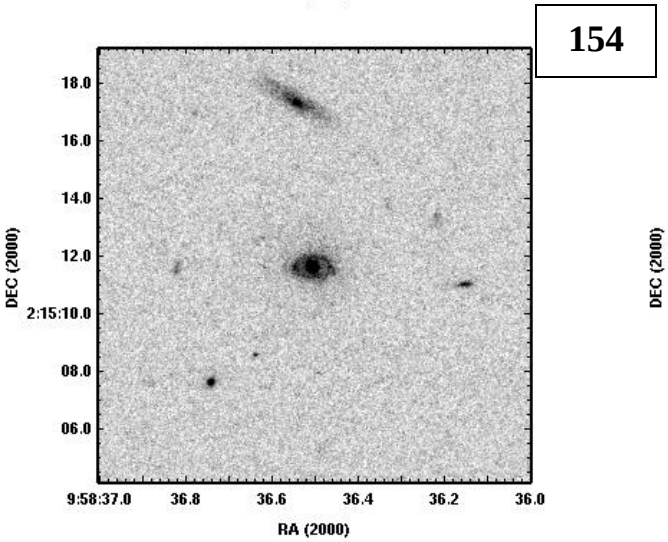
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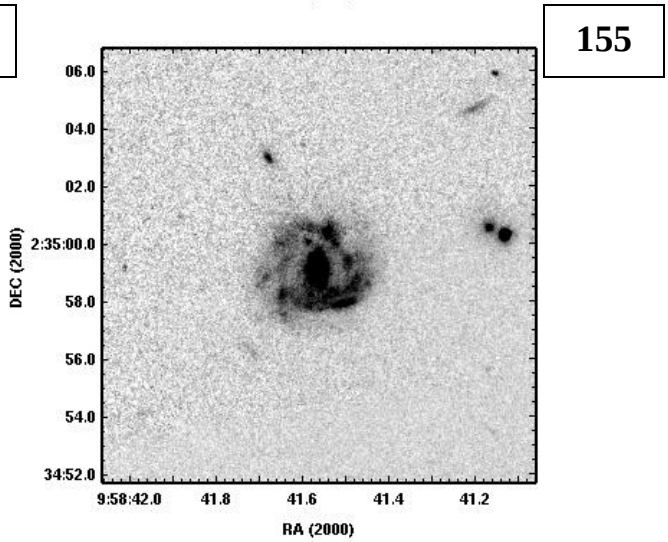
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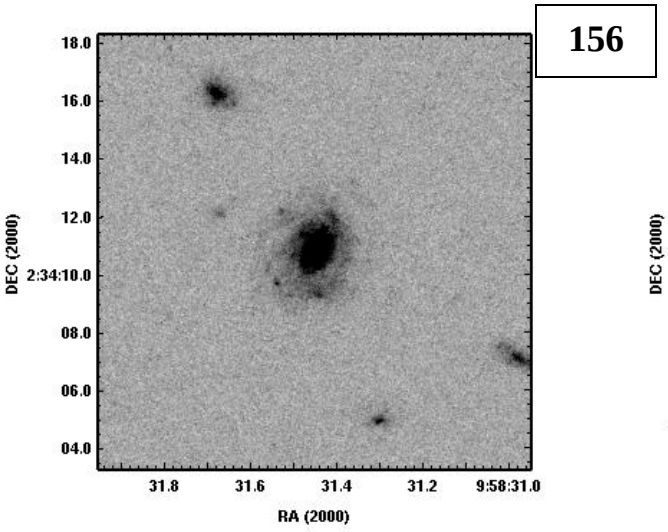
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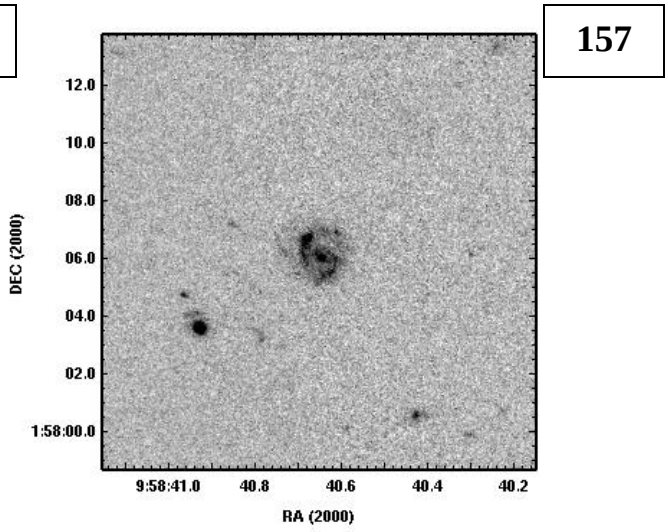
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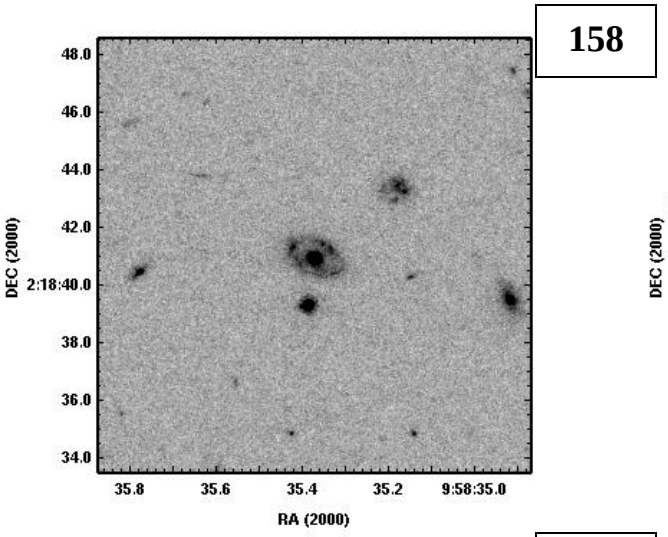
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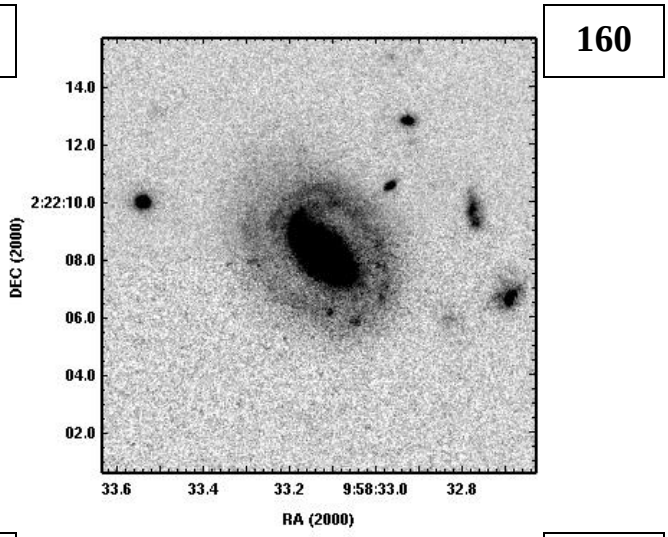
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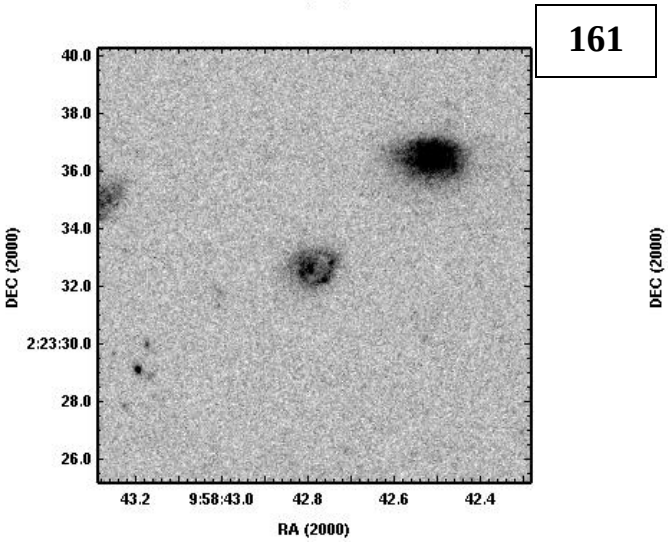
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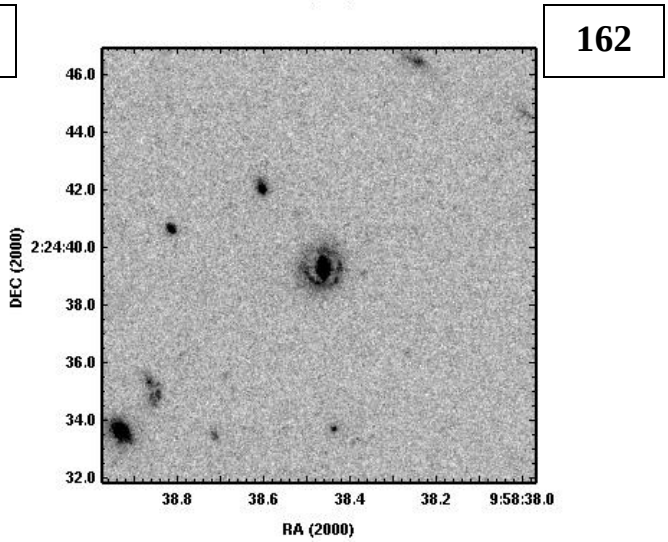
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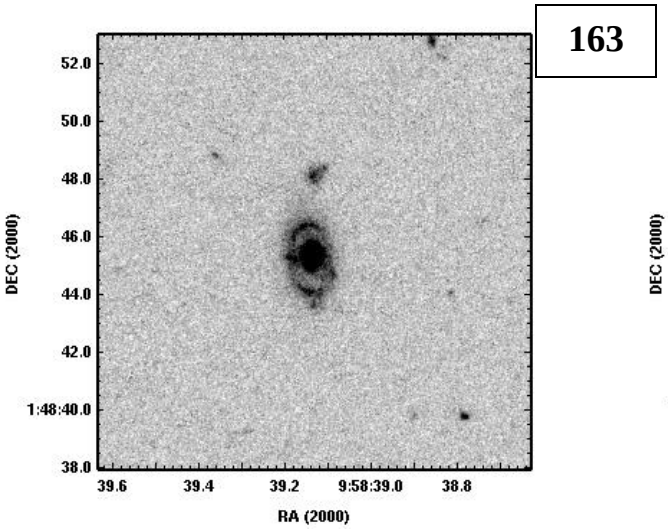
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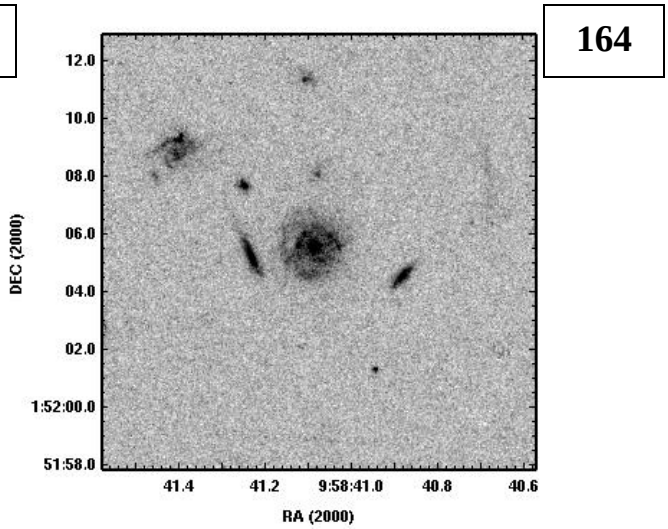
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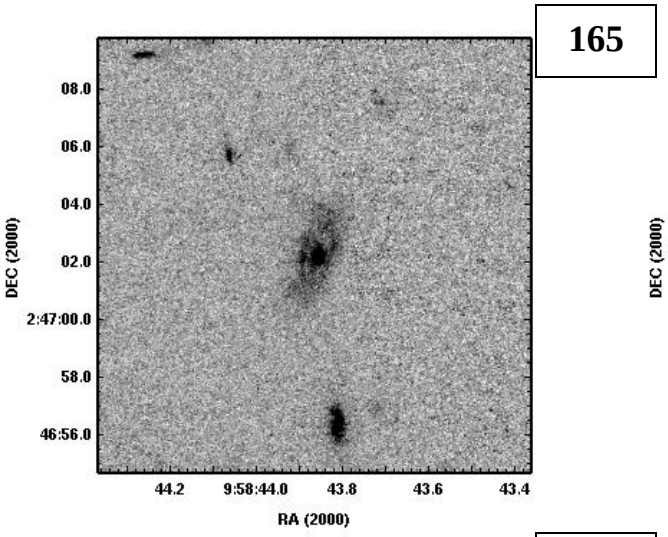
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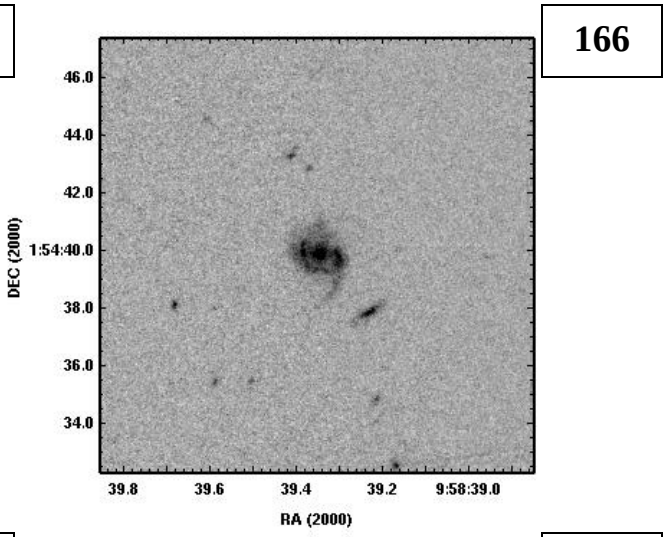
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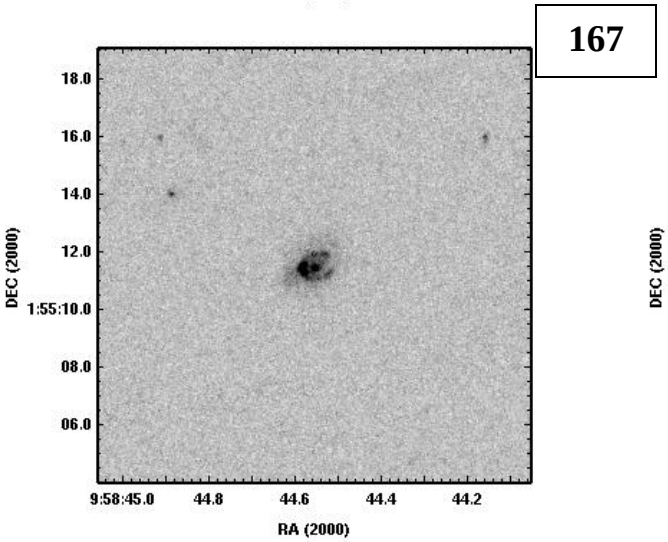
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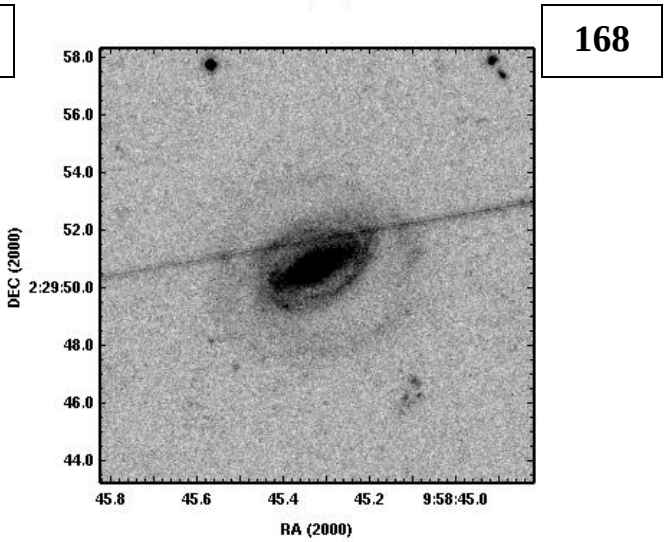
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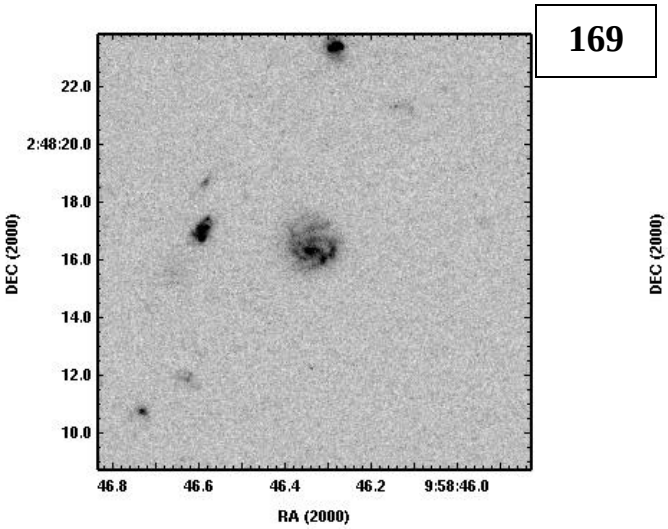
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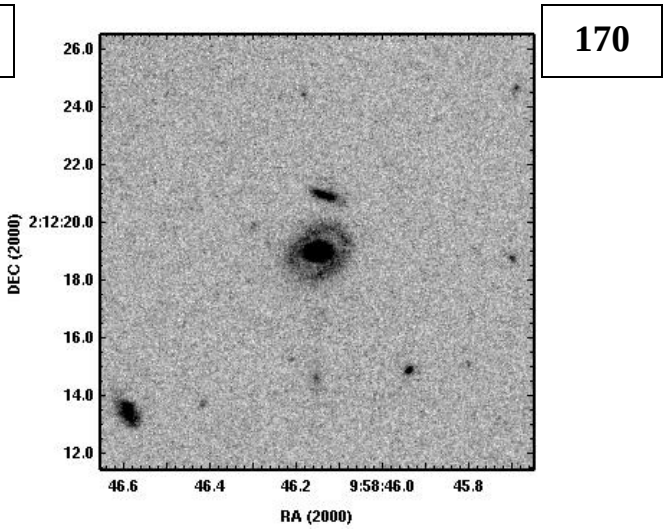
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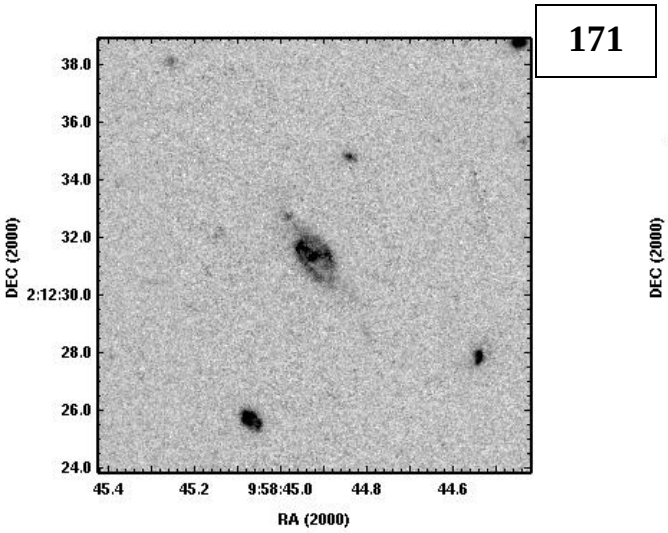
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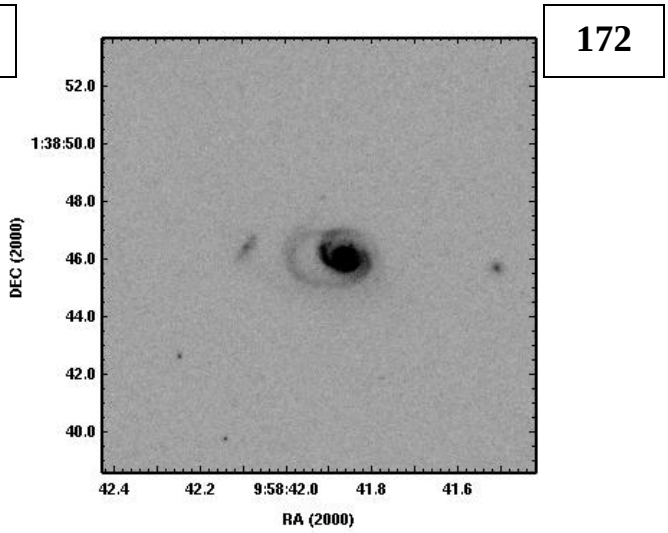
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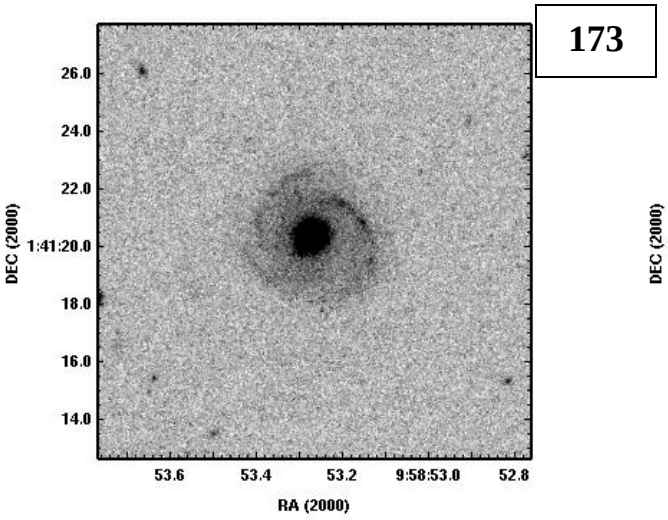
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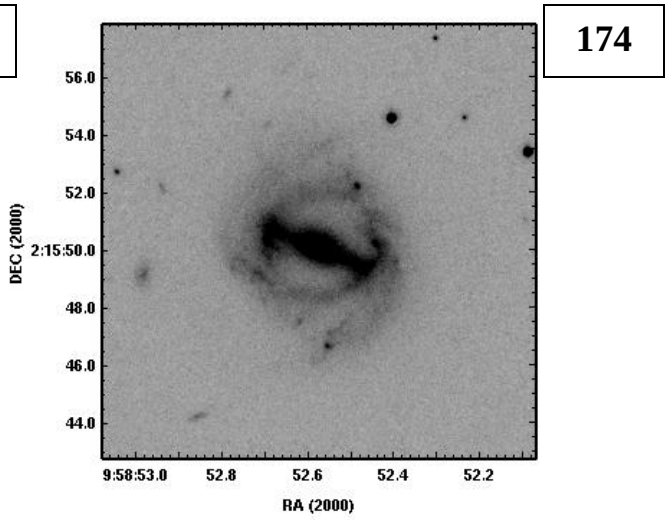
174
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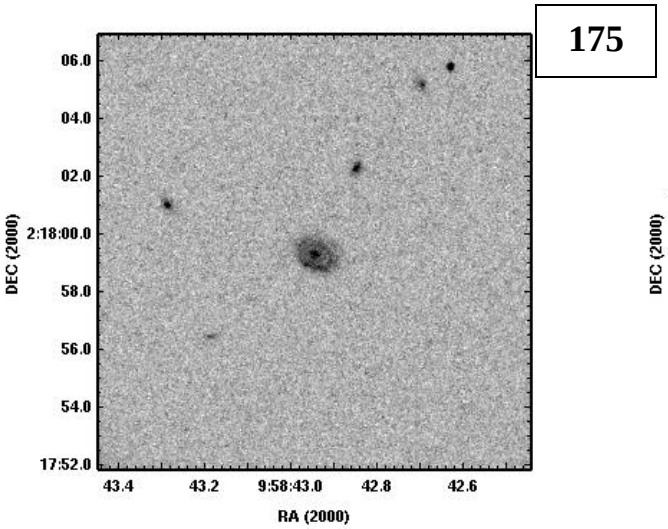
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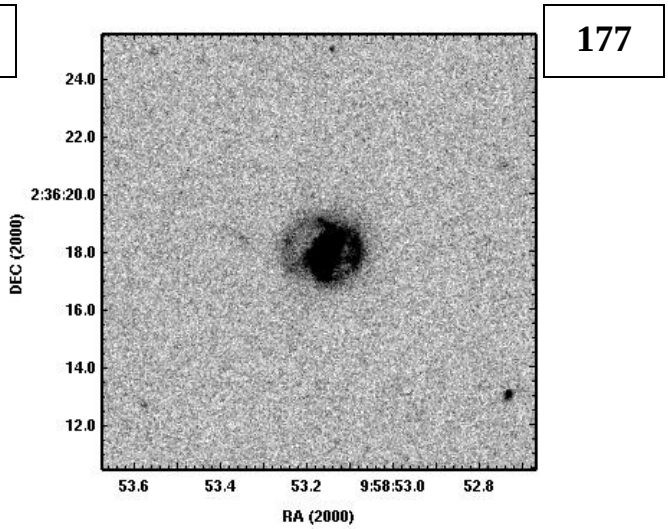
177
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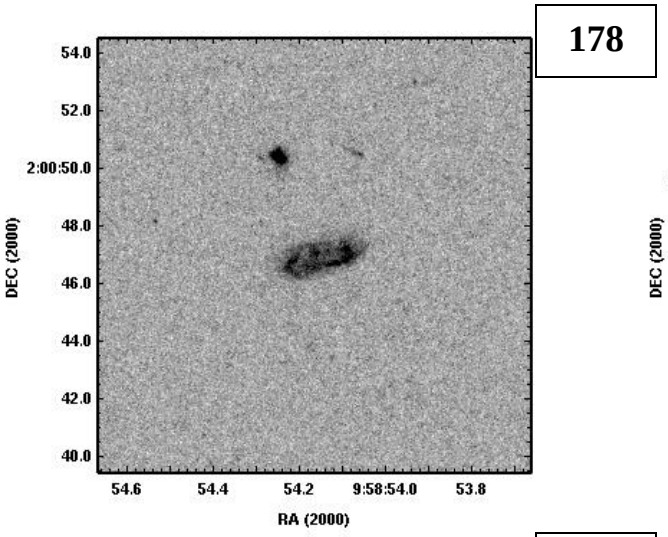
178
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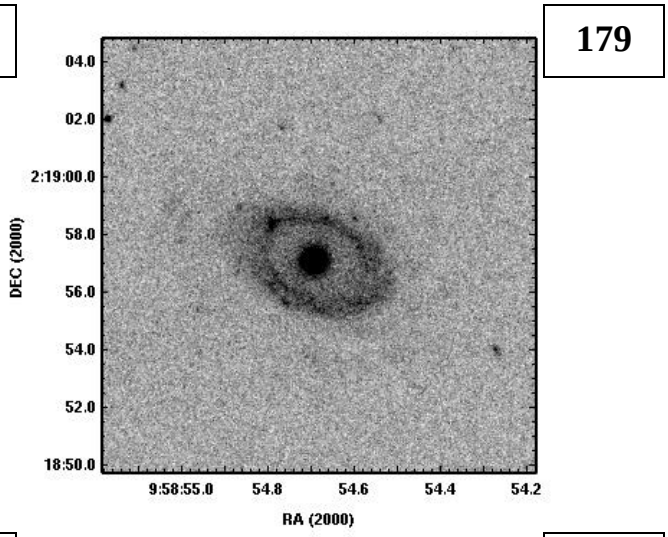
179
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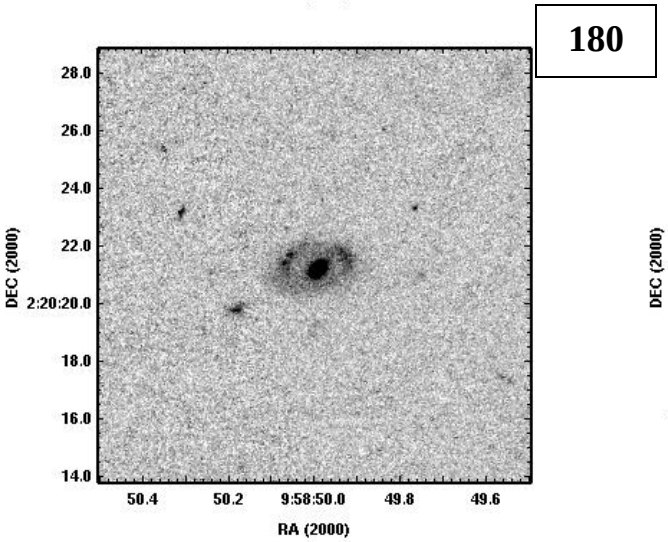
180
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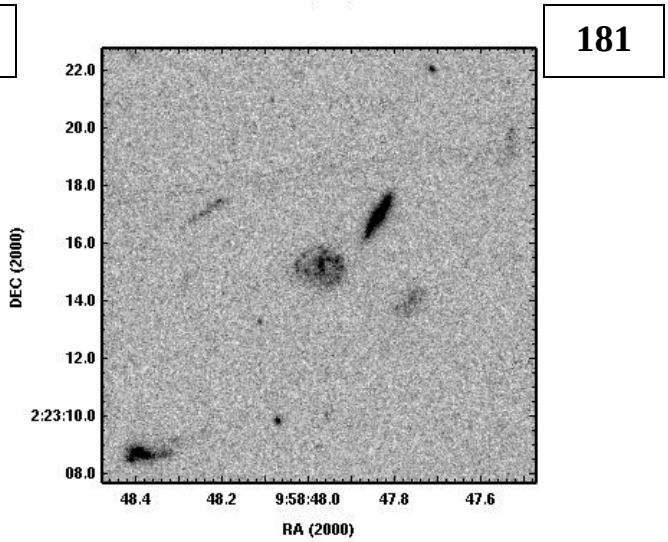
181
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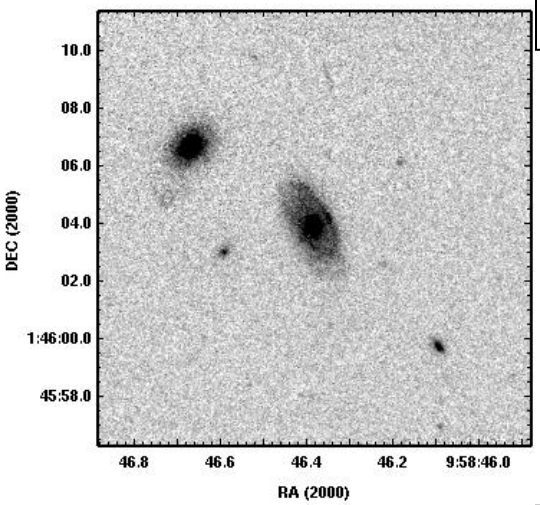
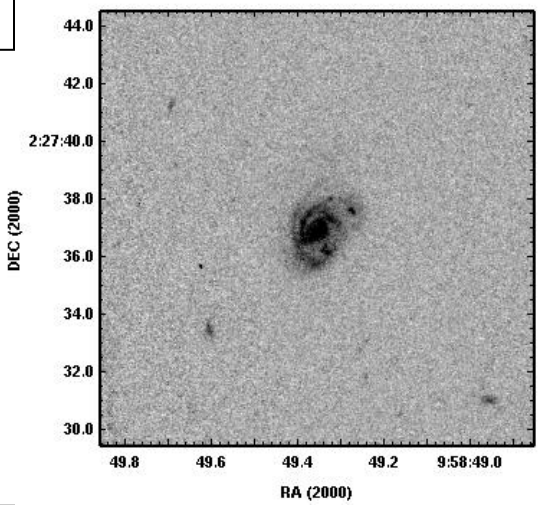
RA (2000)

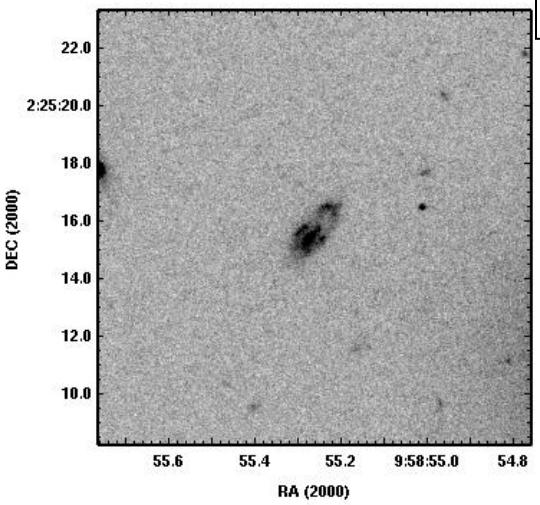
182



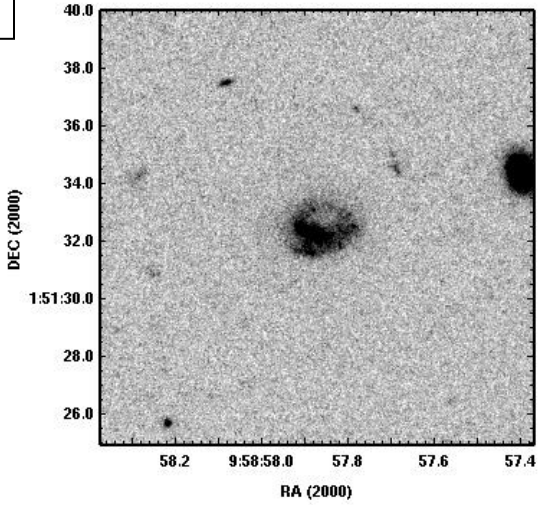
183



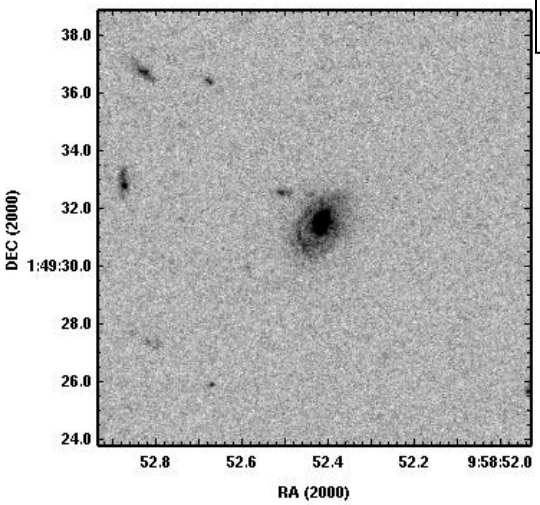
184



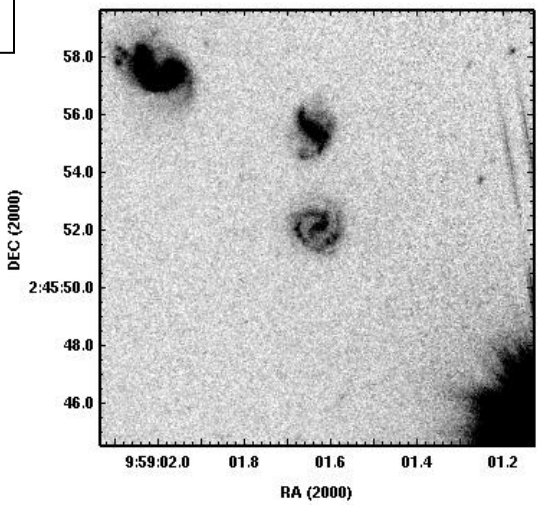
185

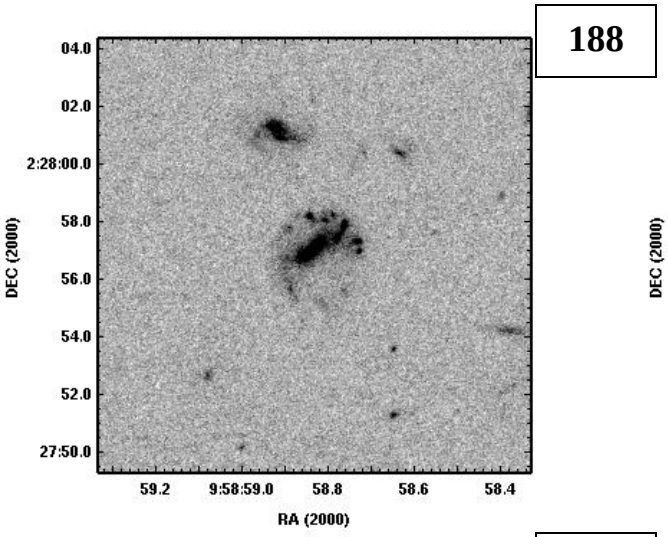


186



187

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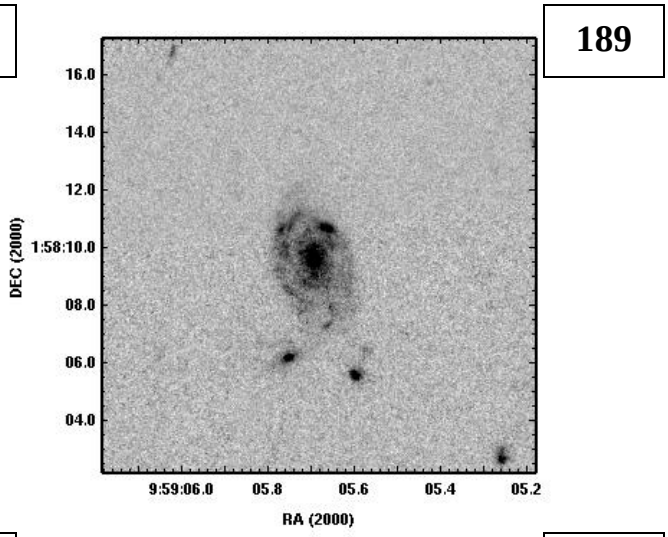
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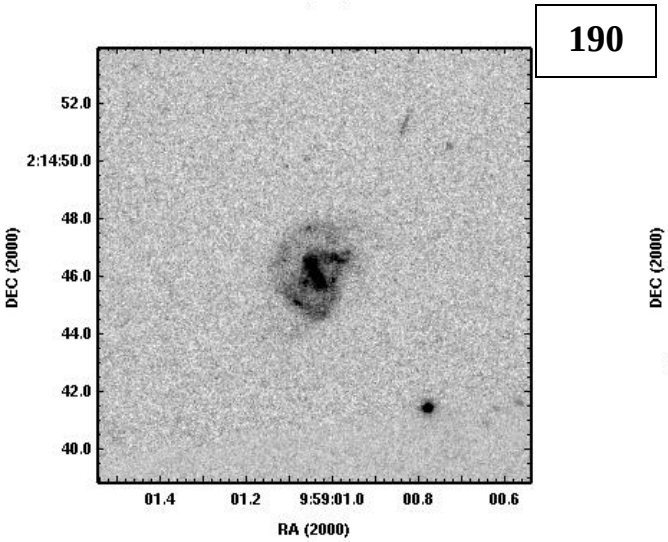
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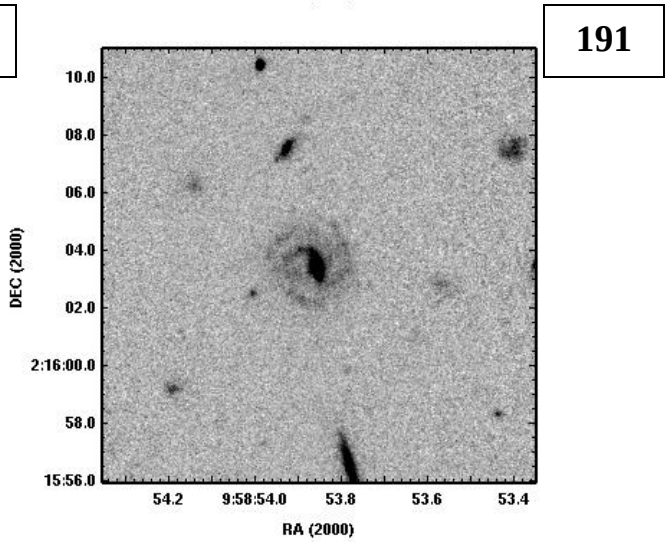
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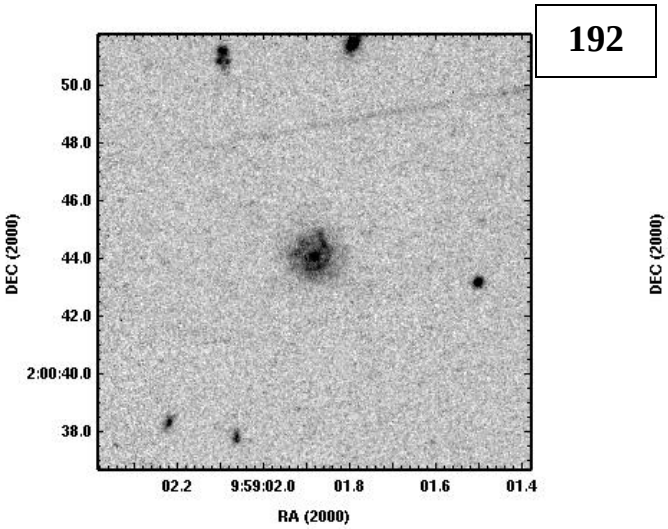
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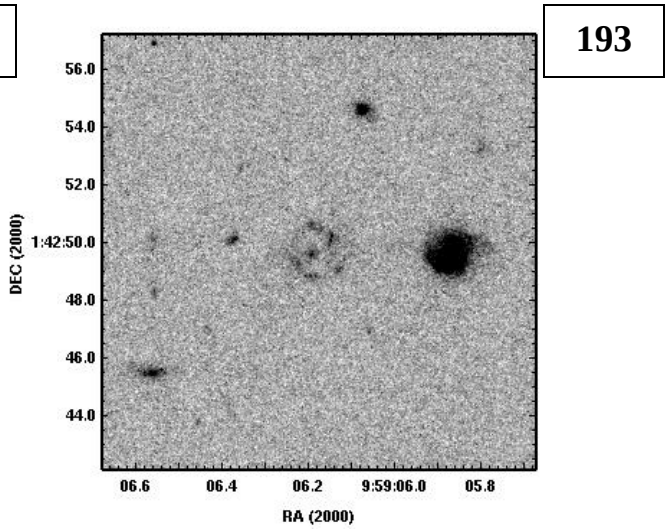
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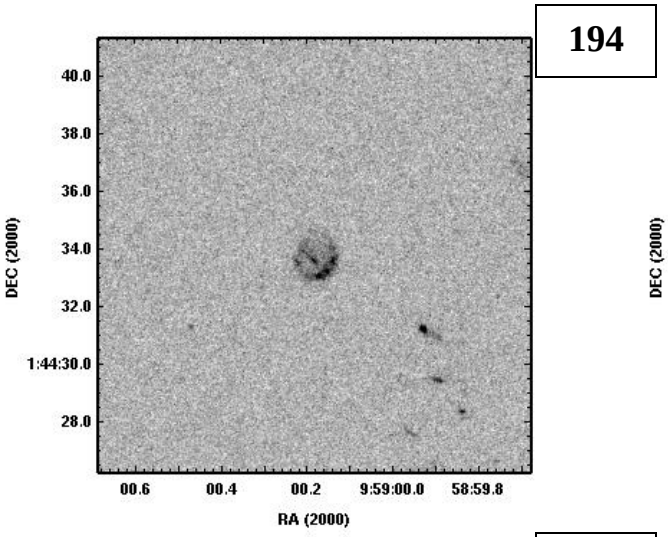
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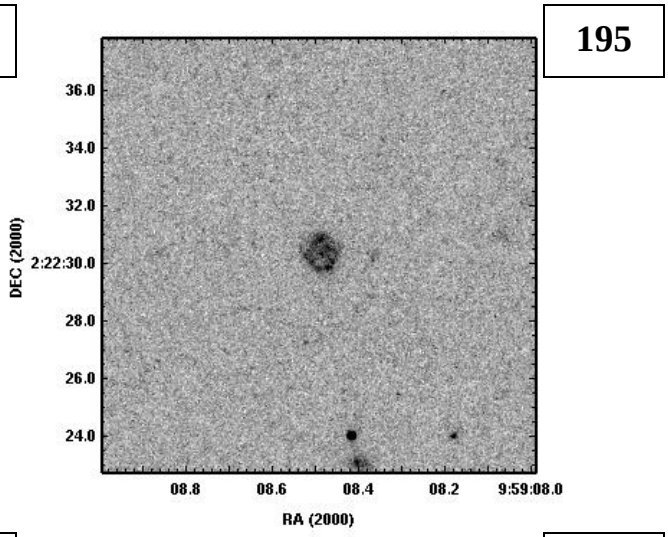
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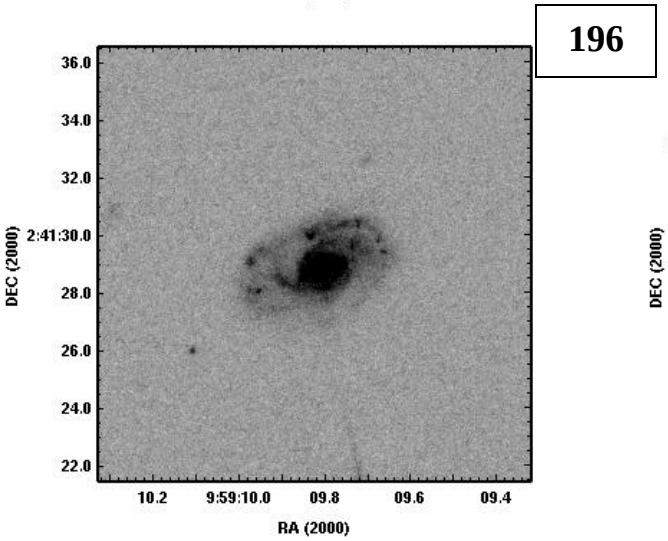
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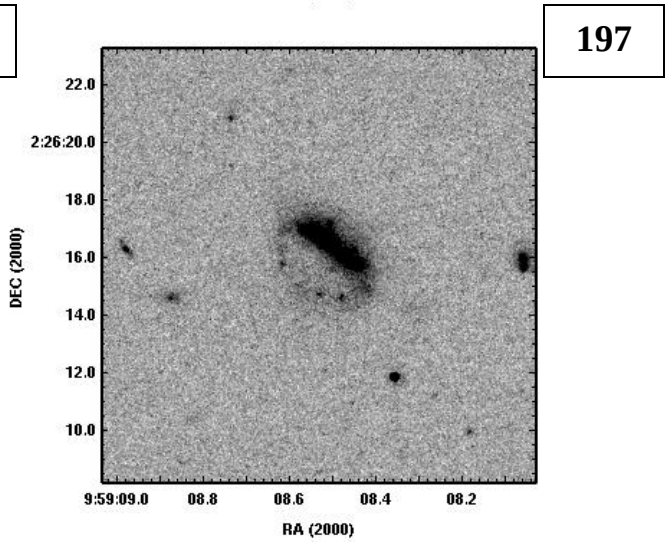
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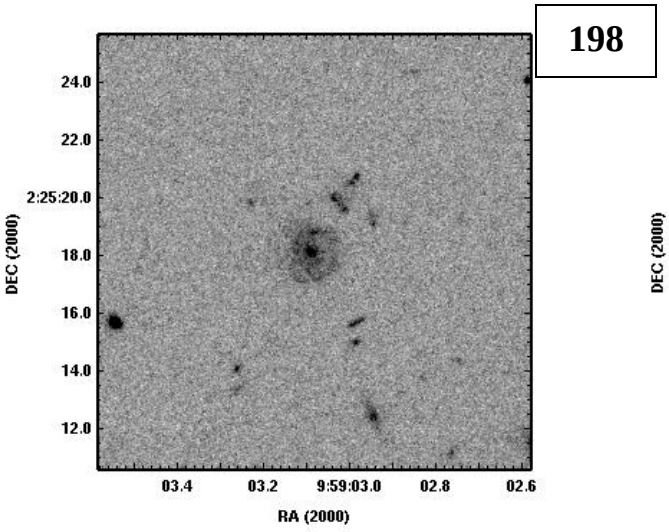
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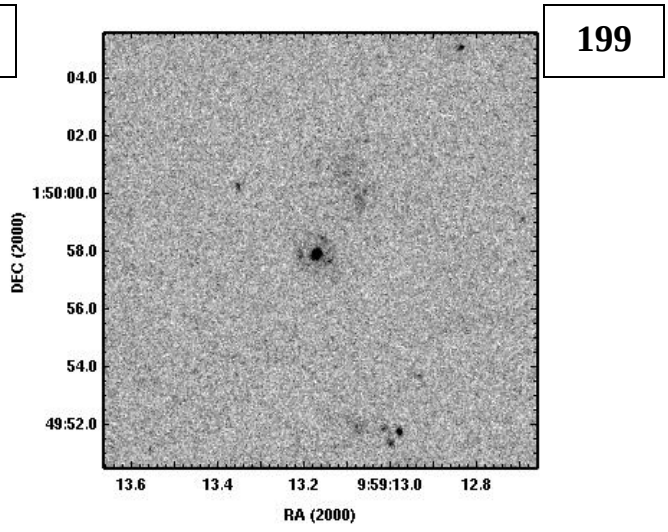
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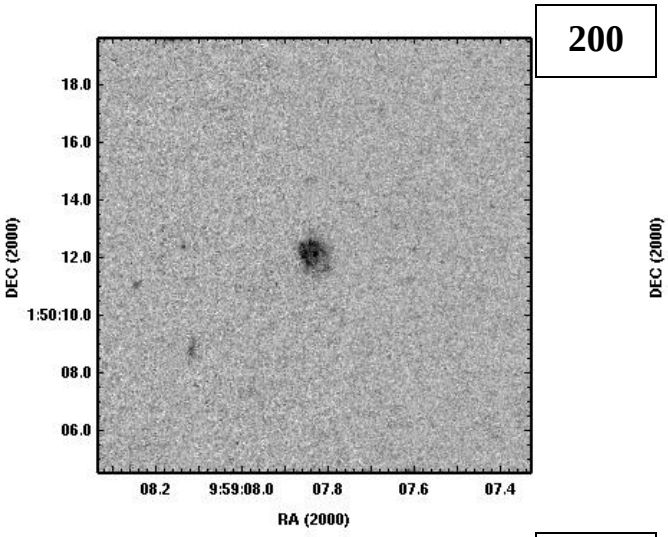
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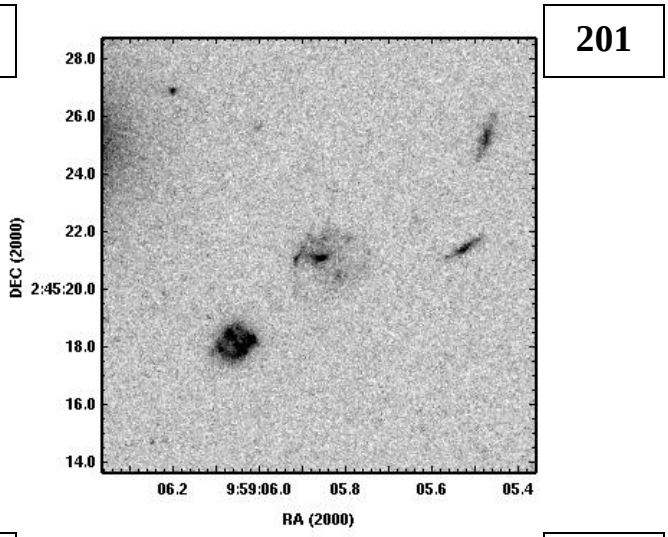
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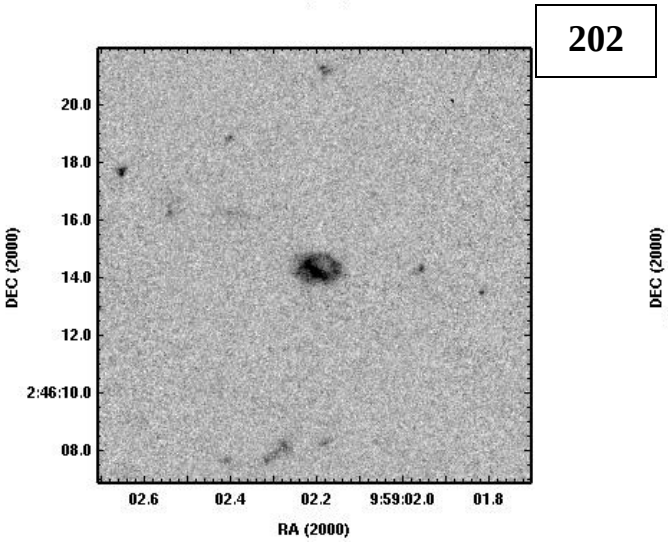
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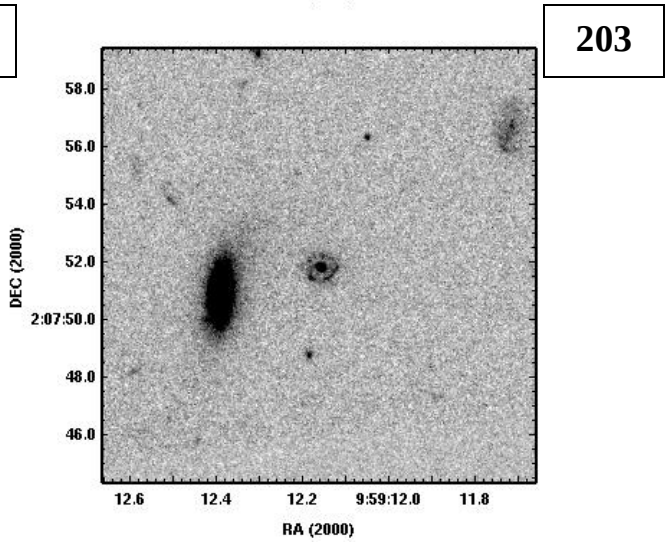
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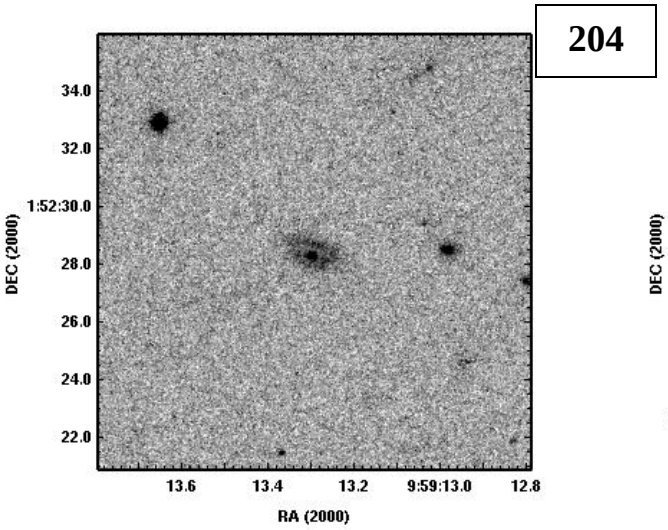
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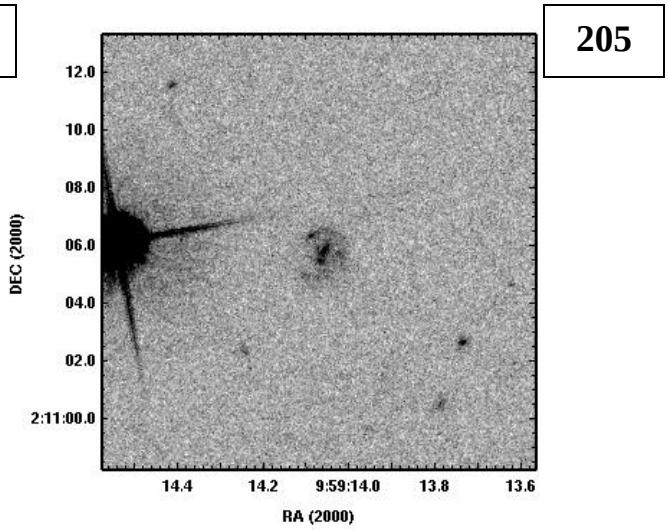
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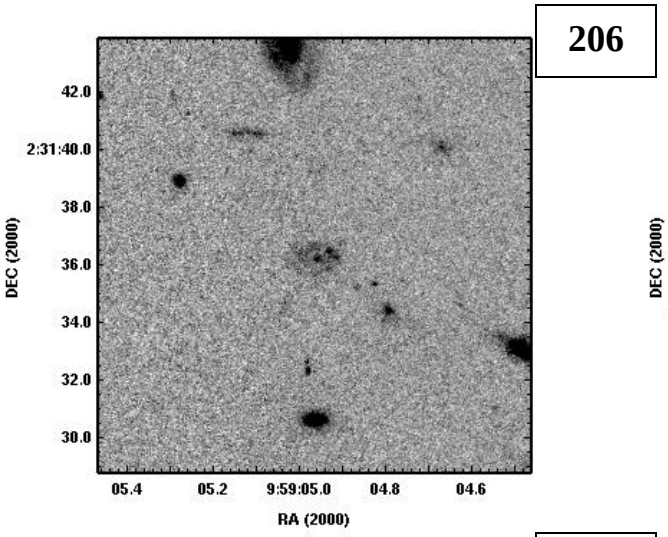
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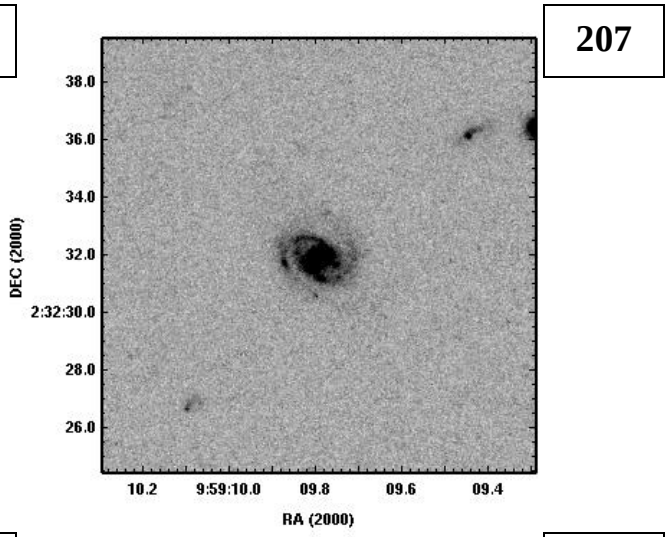
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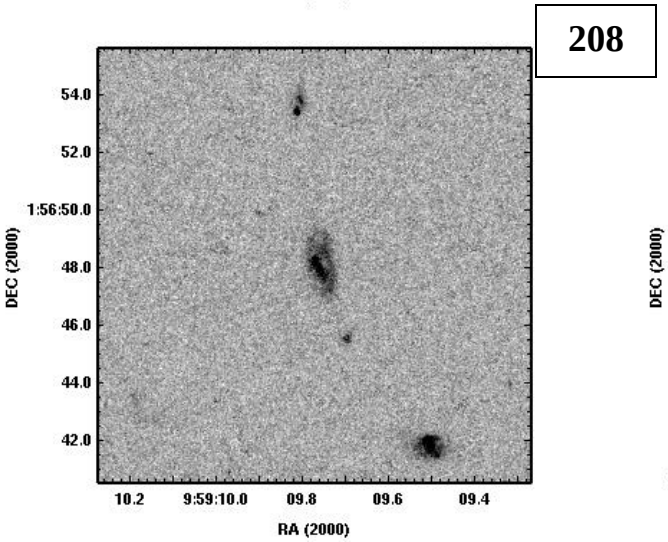
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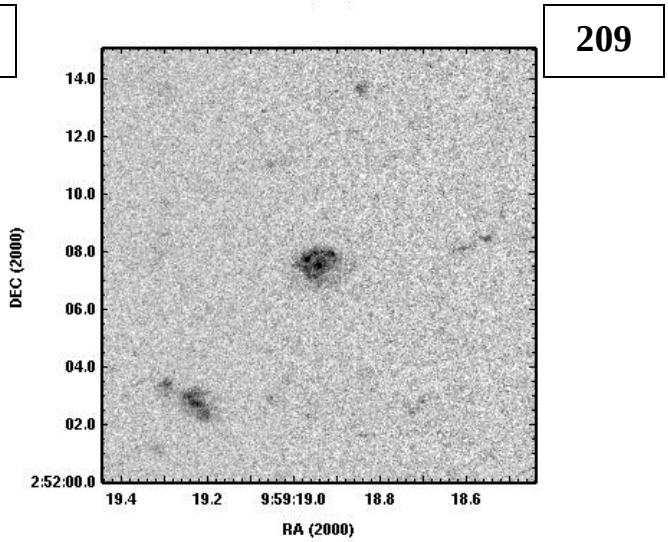
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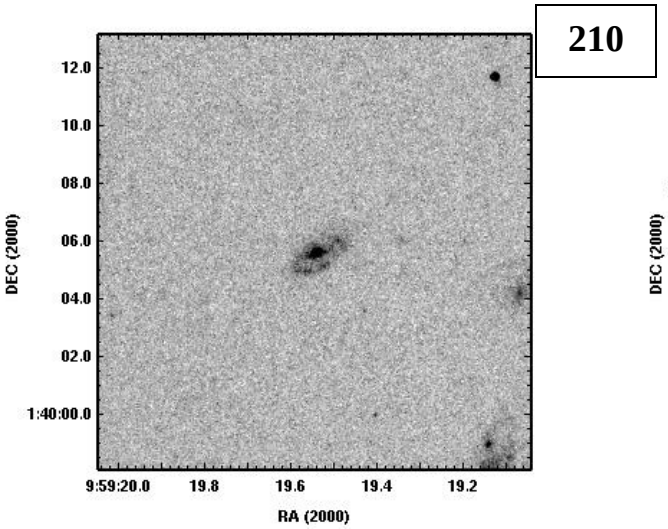
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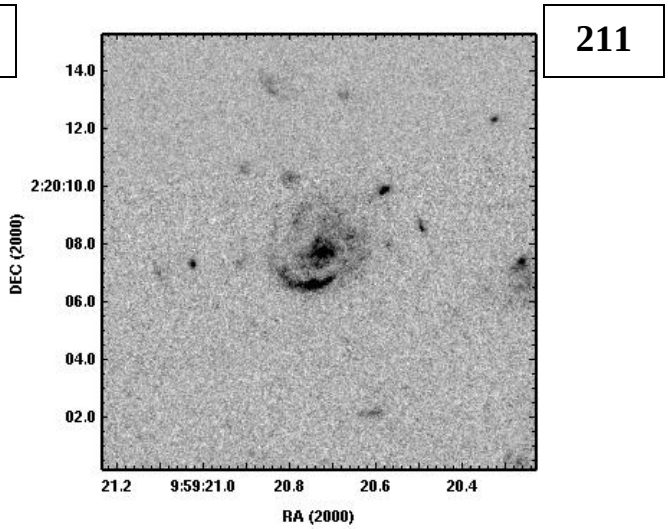
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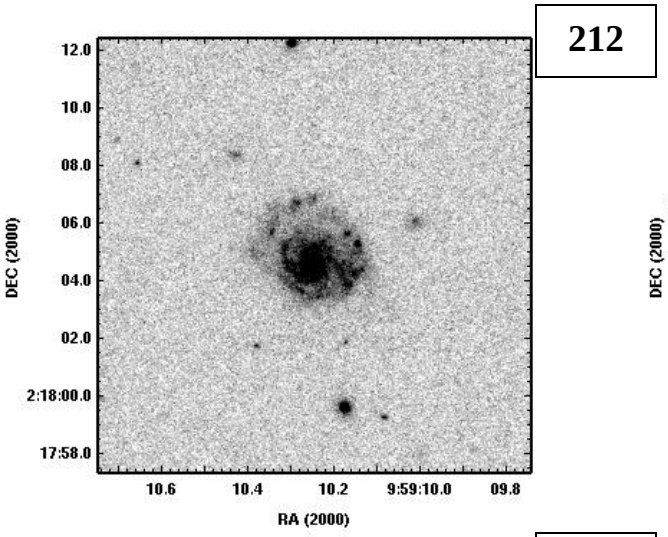
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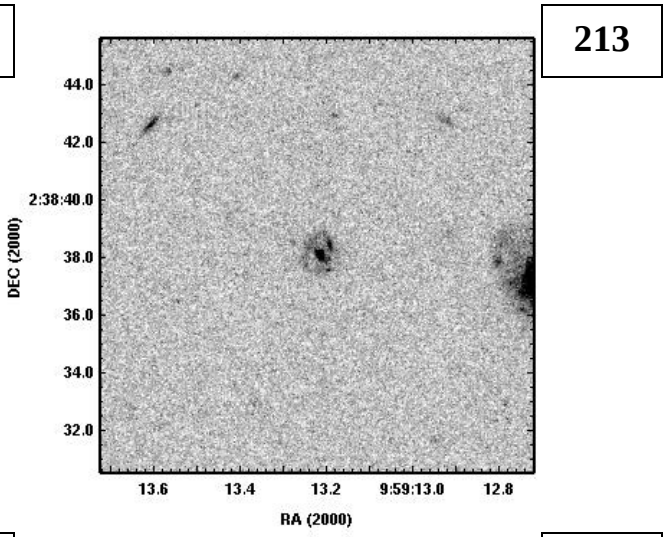
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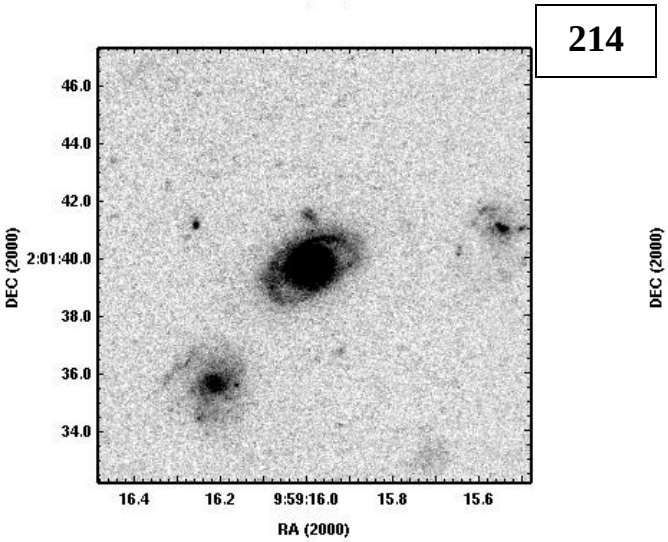
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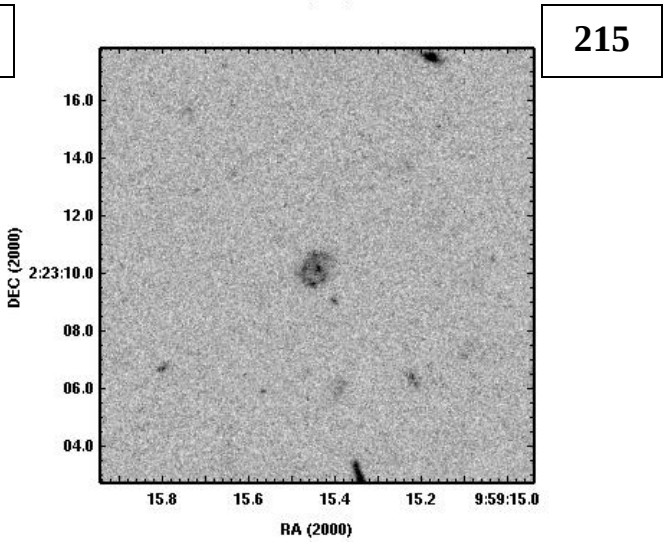
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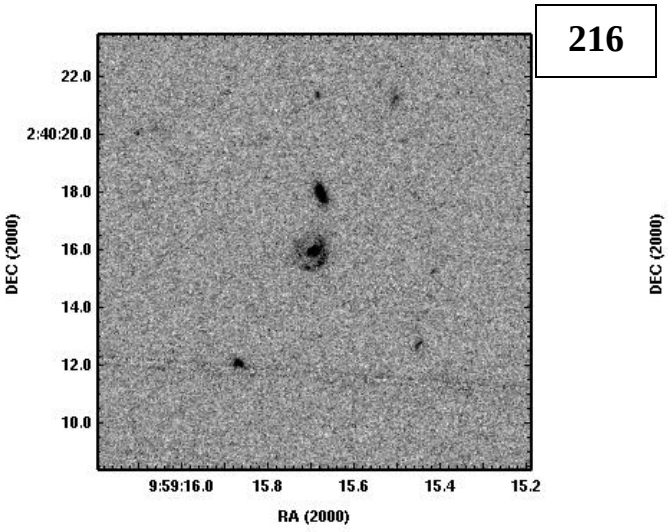
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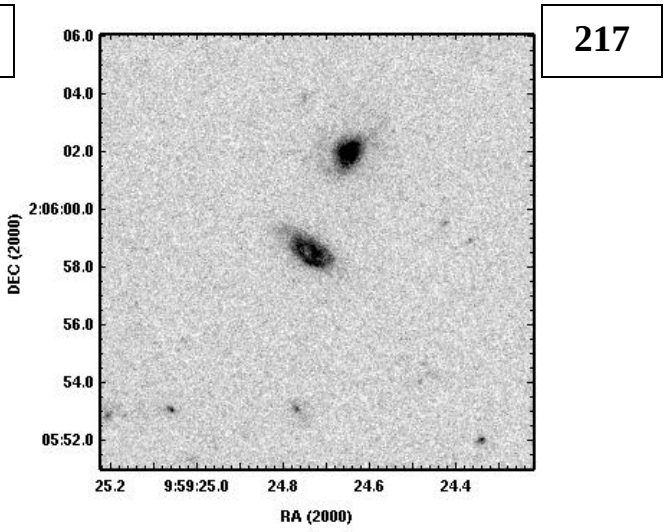
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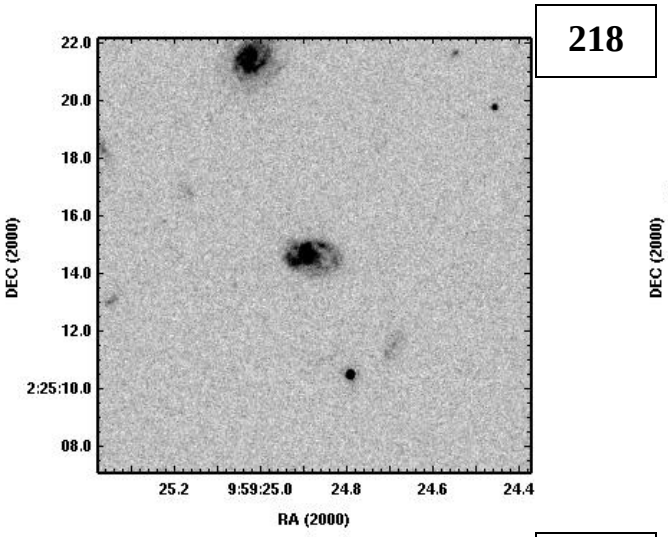
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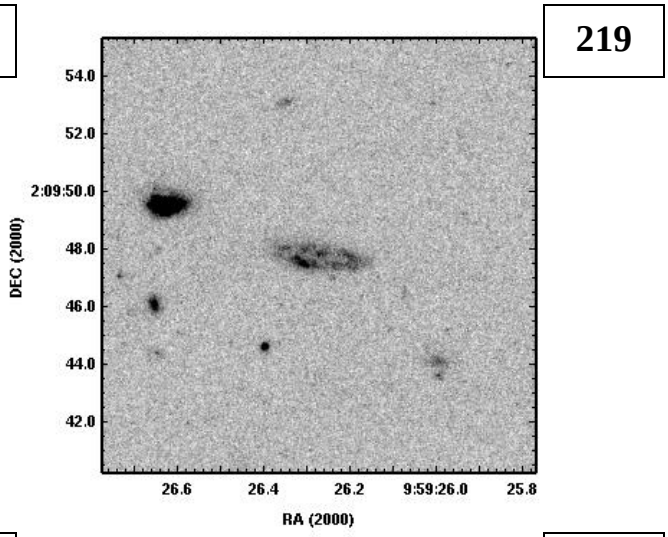
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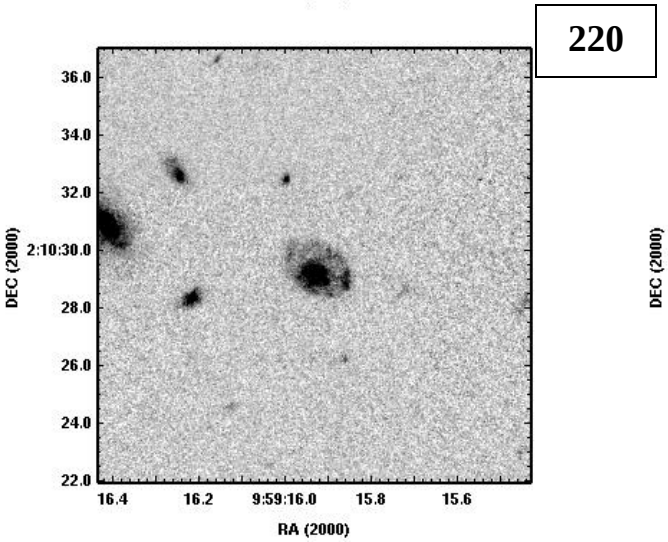
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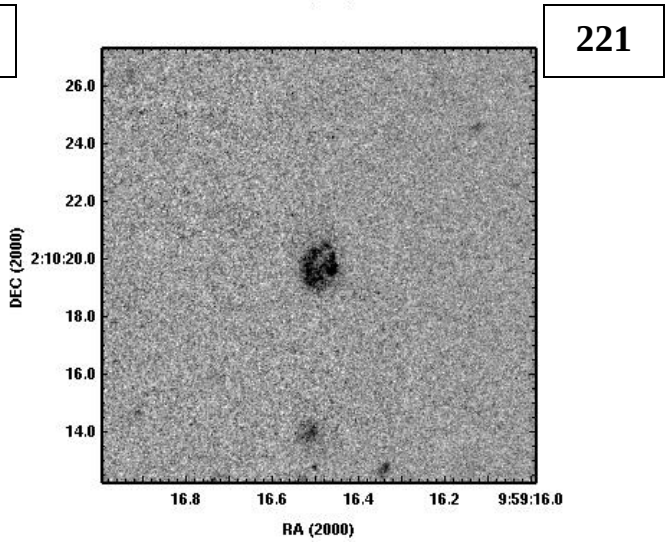
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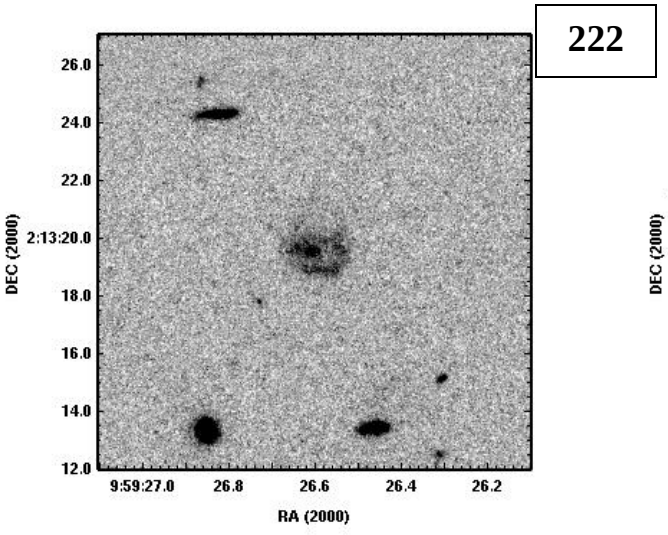
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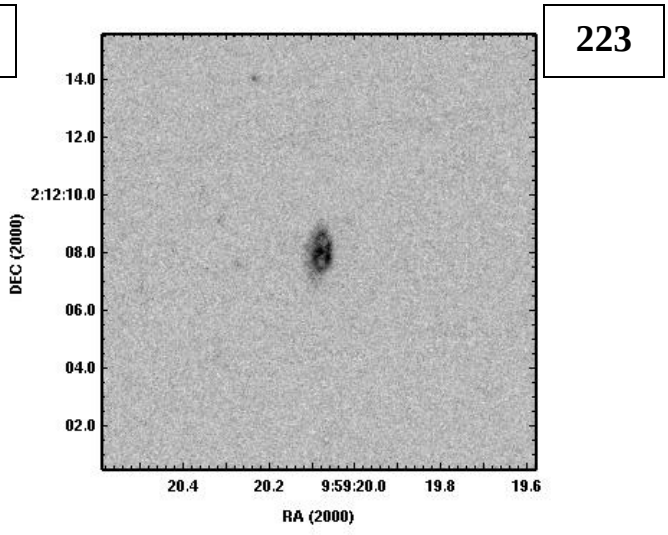
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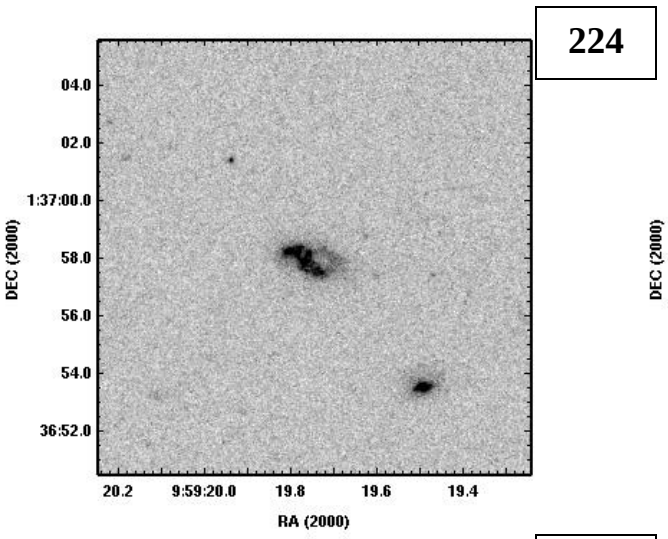
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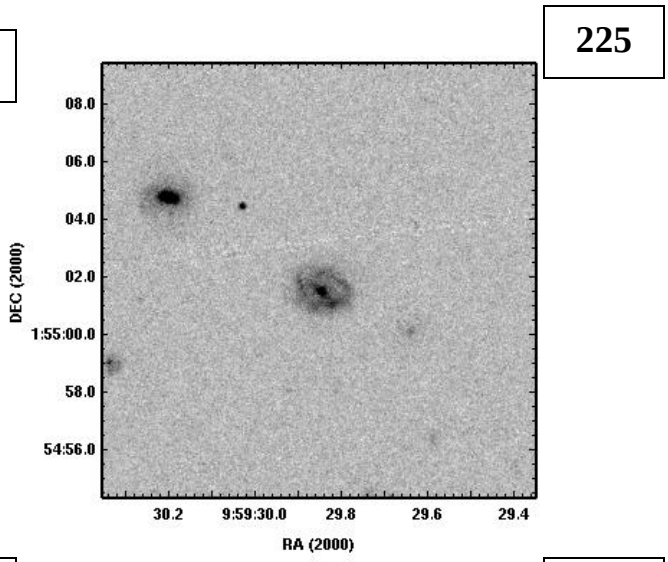
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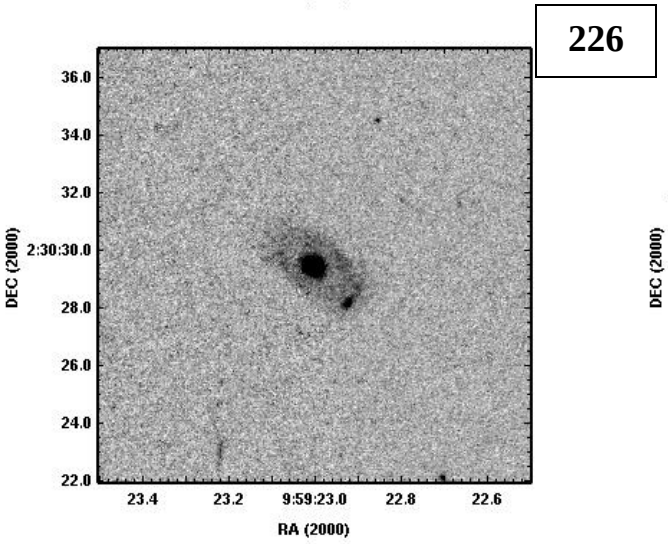
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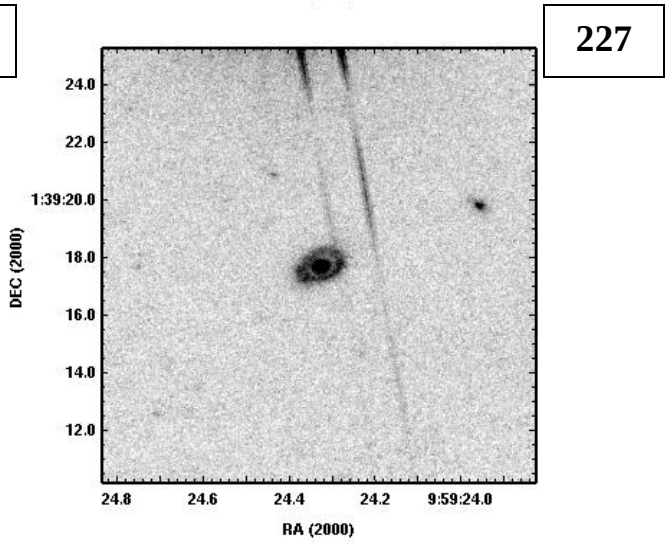
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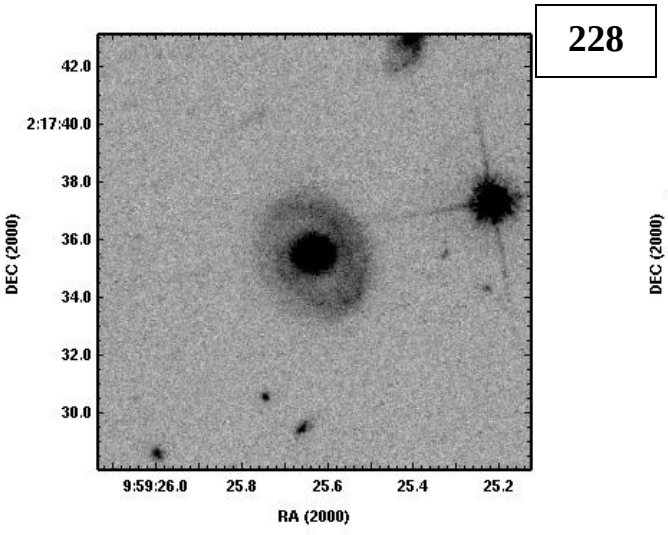
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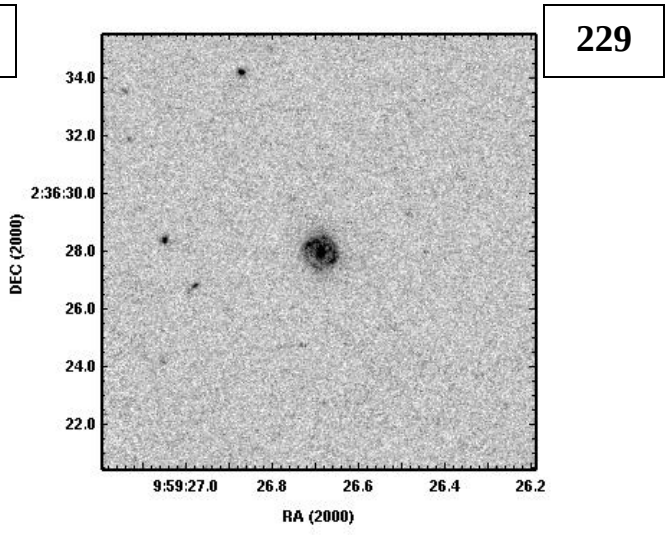
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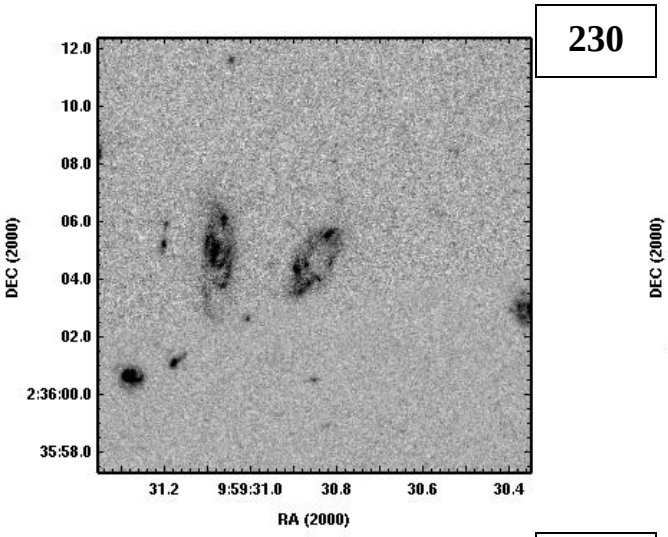
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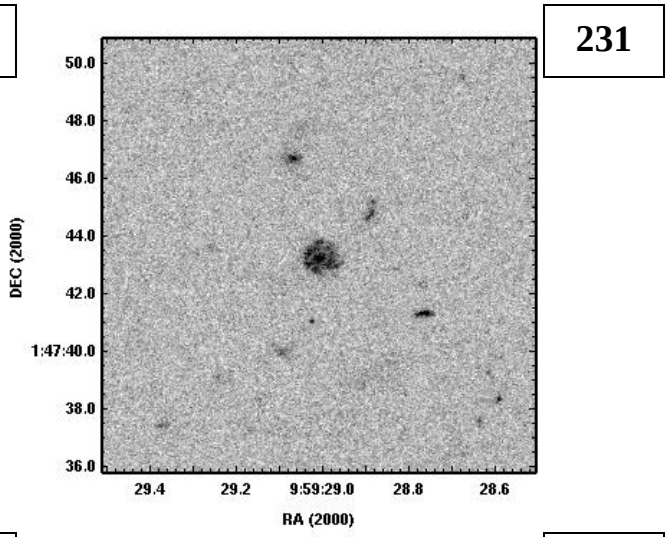
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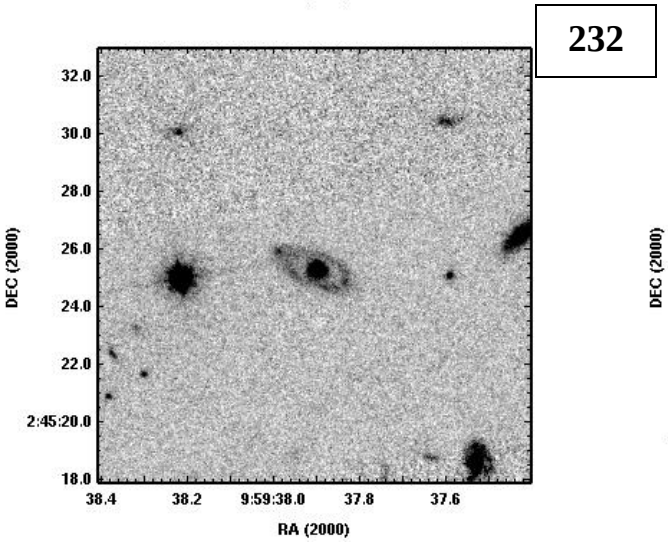
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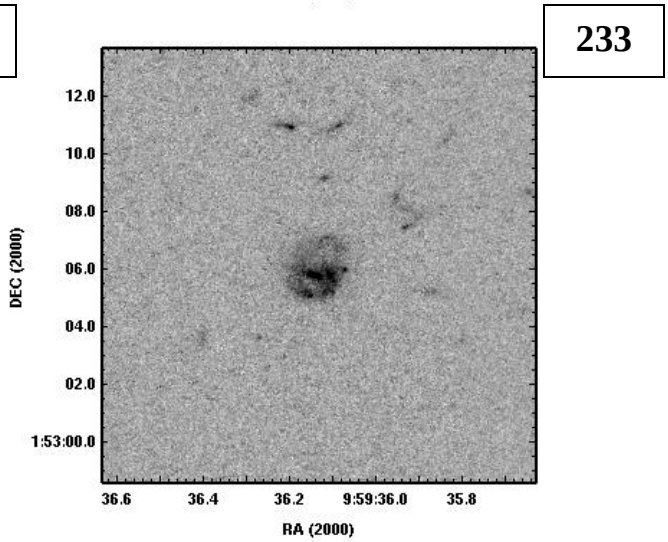
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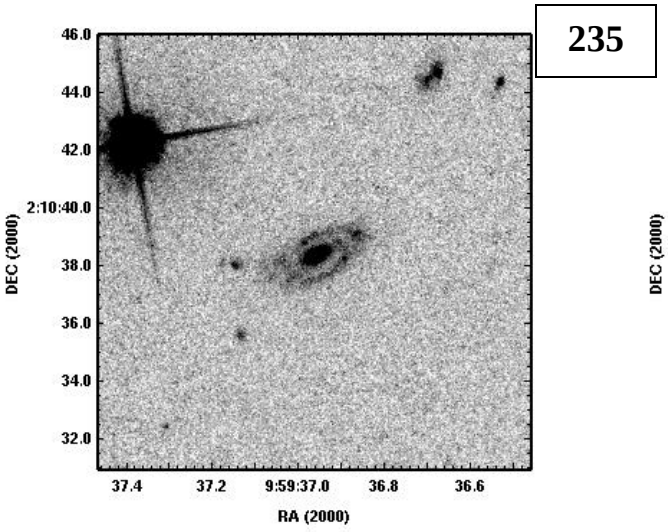
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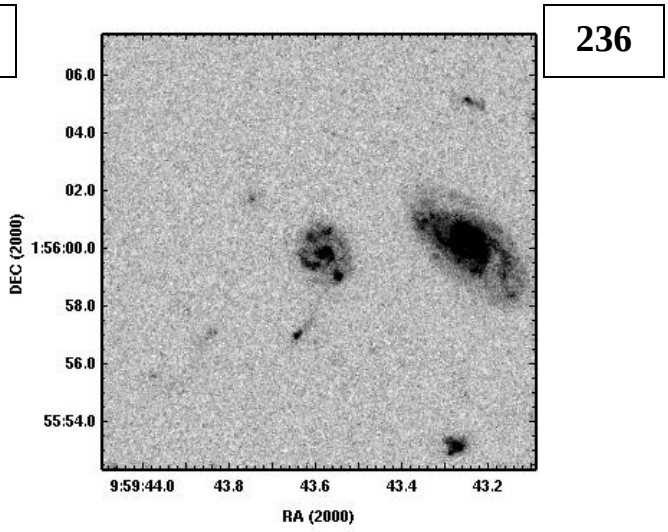
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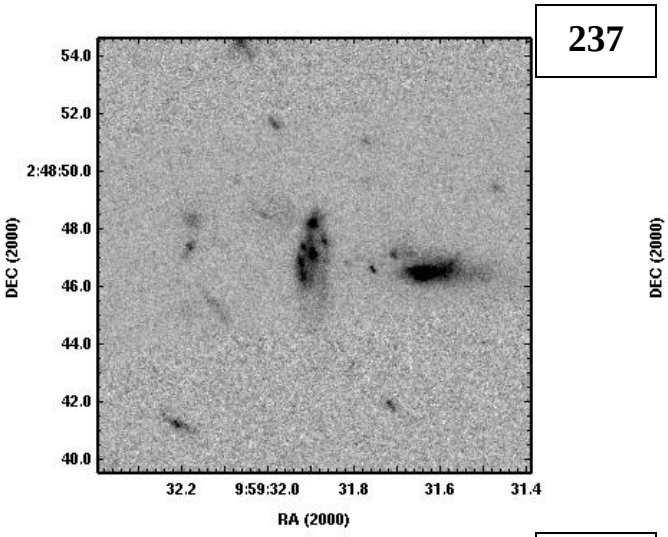
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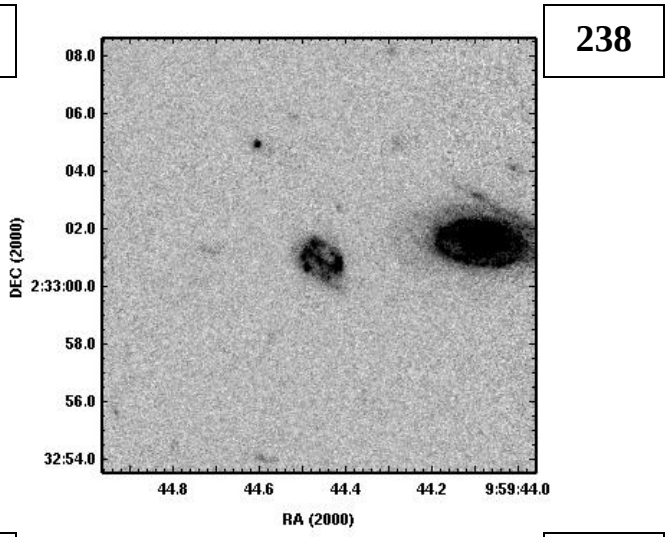
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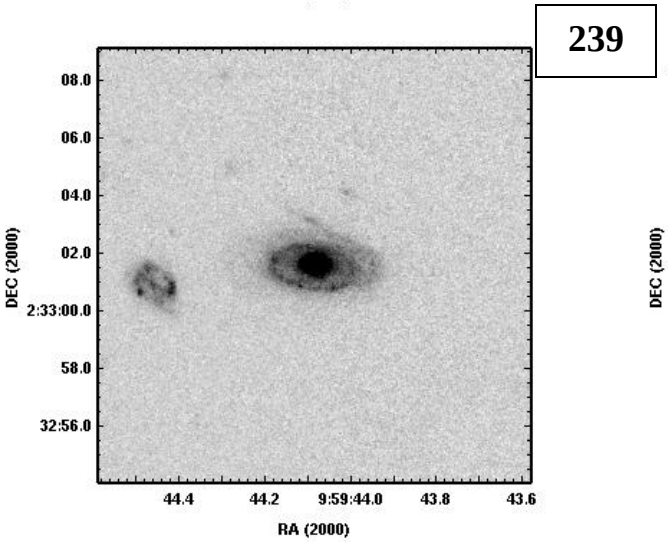
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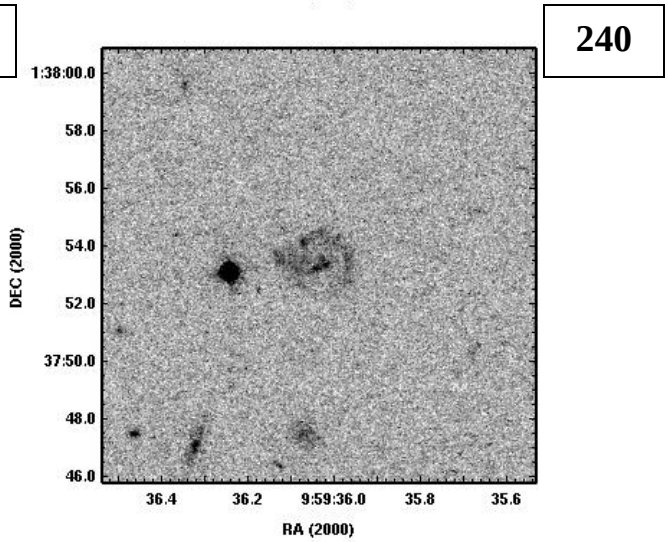
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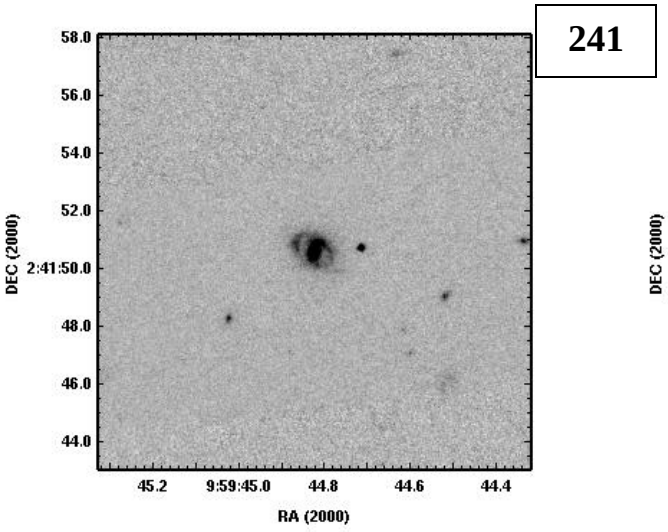
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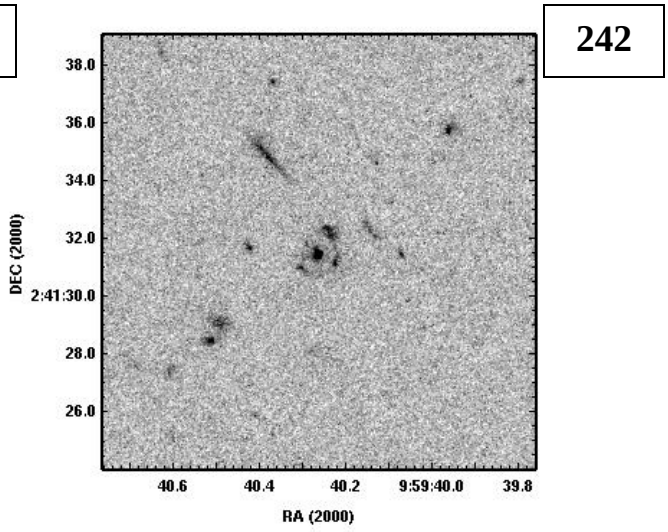
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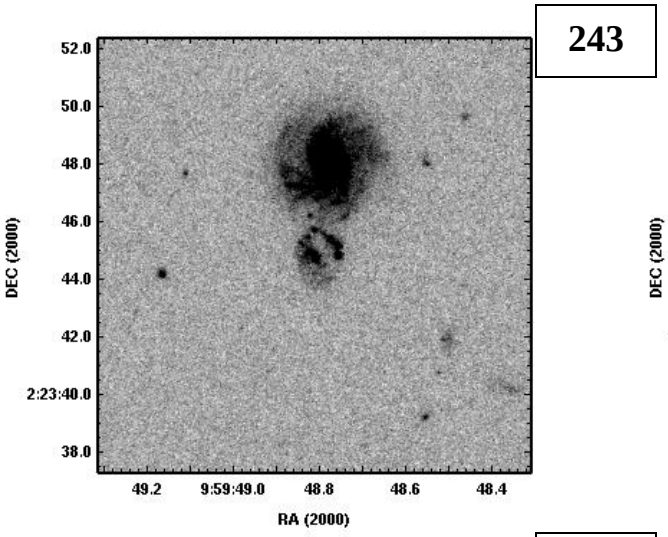
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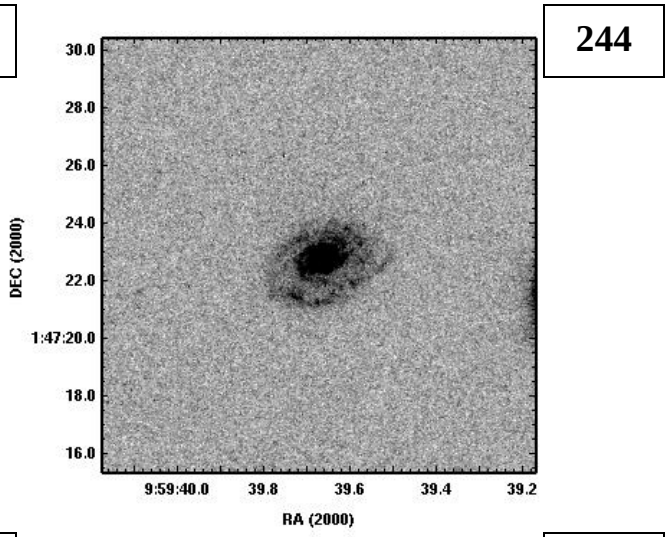
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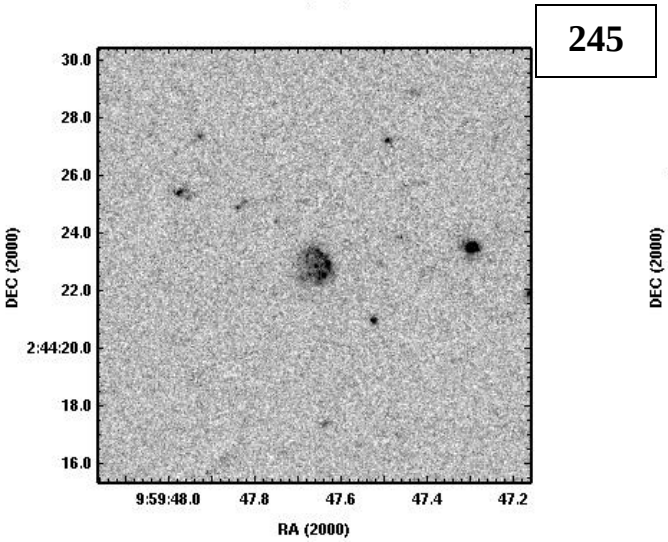
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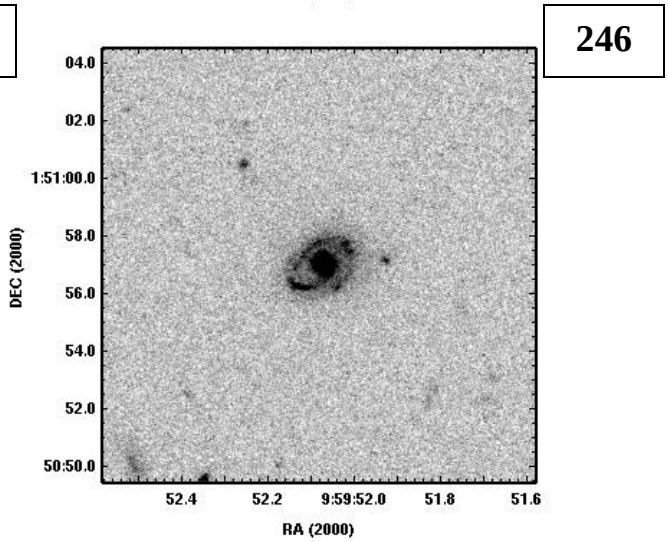
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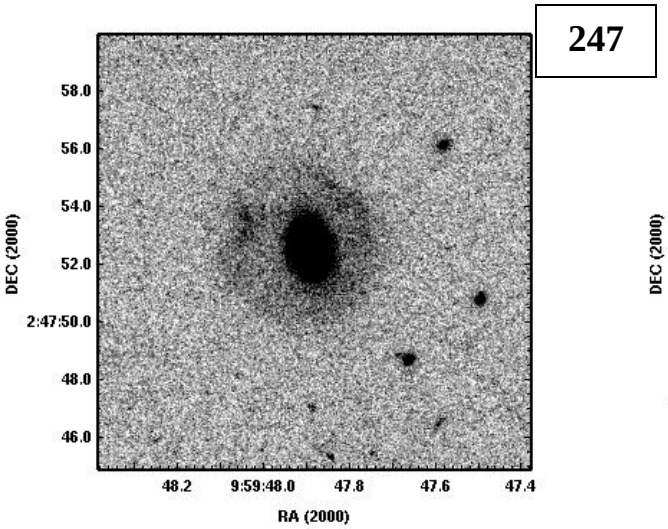
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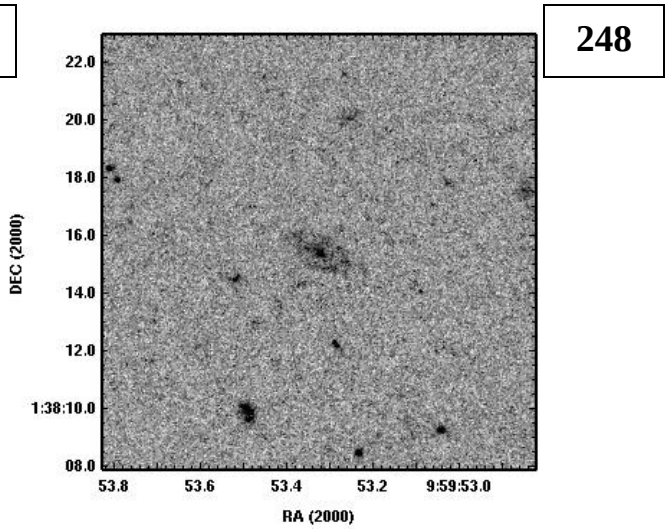
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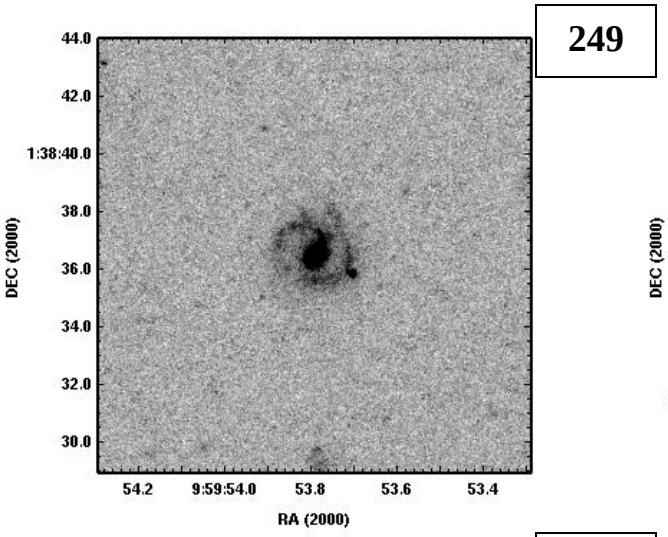
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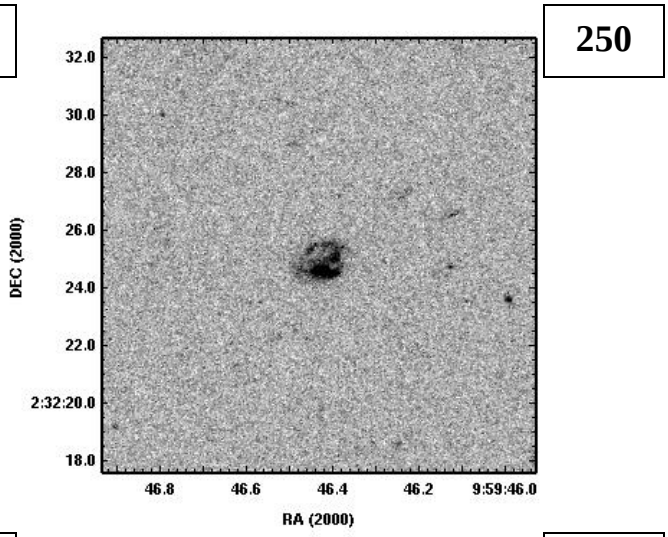
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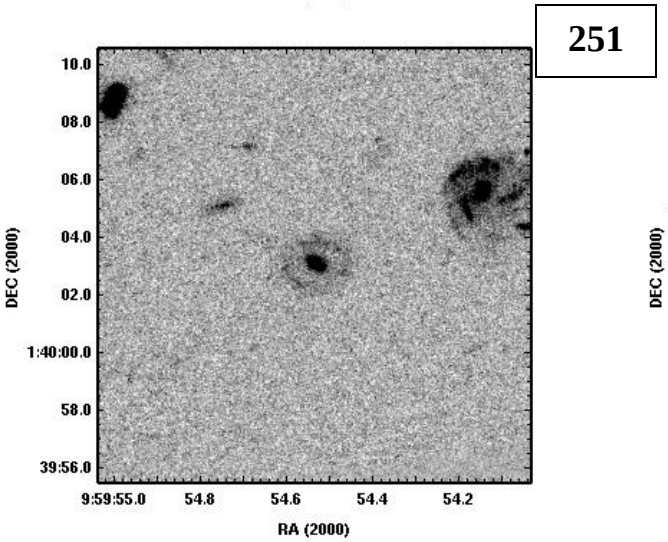
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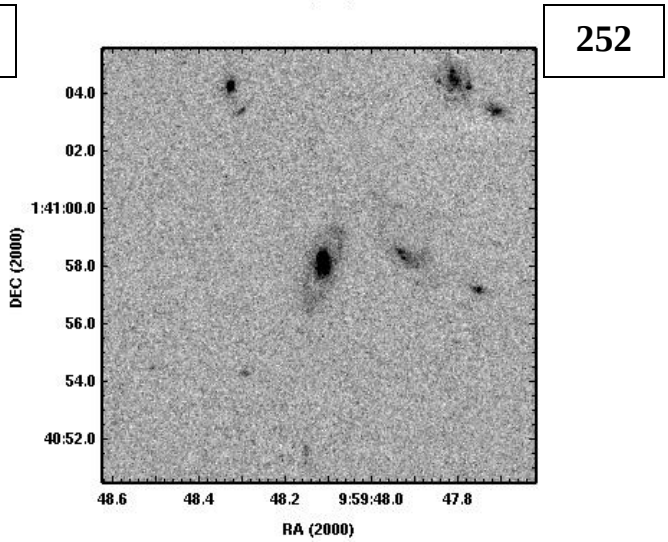
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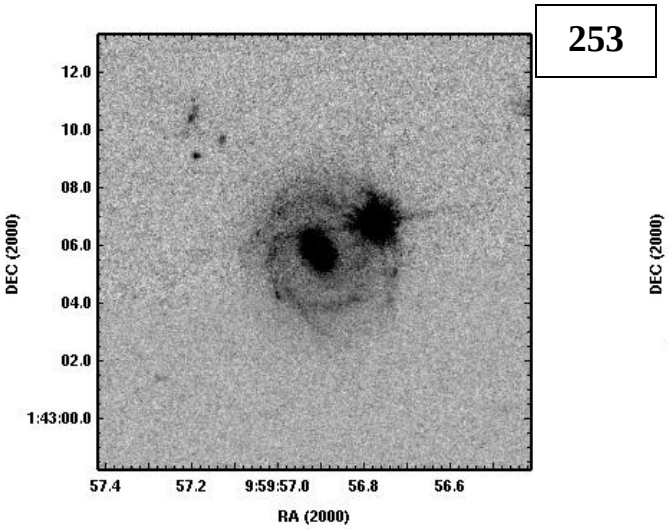
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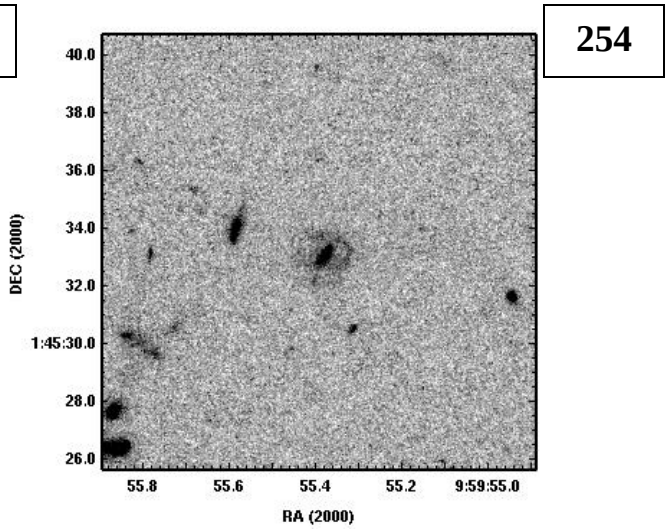
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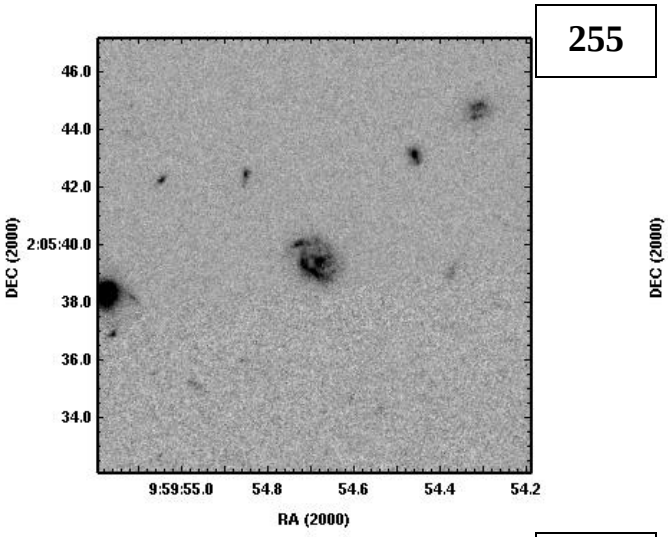
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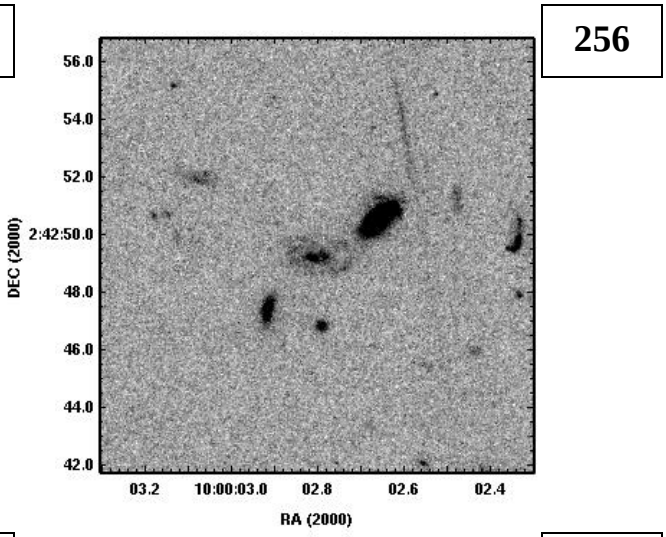
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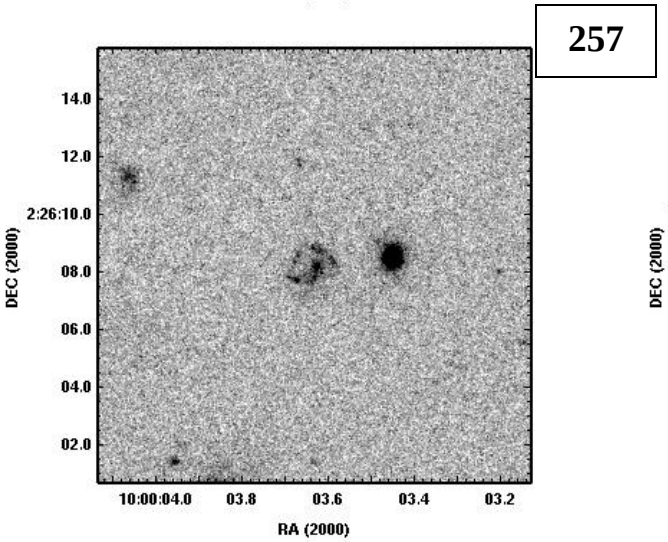
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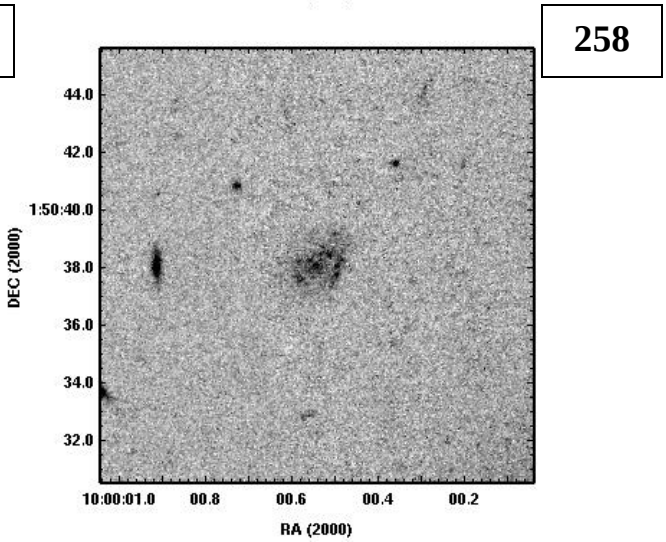
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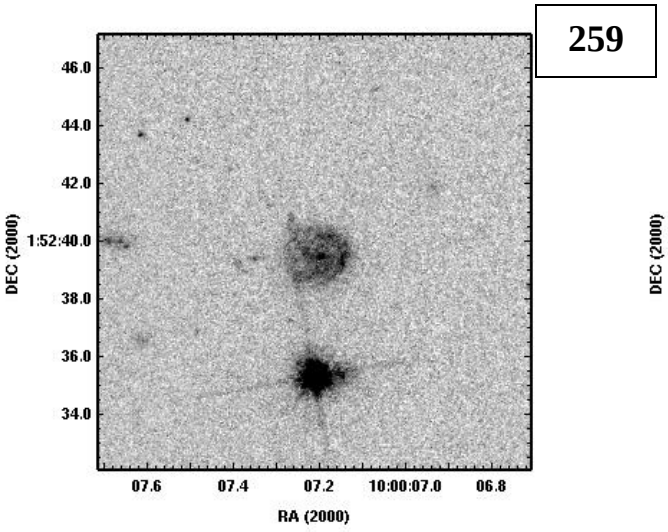
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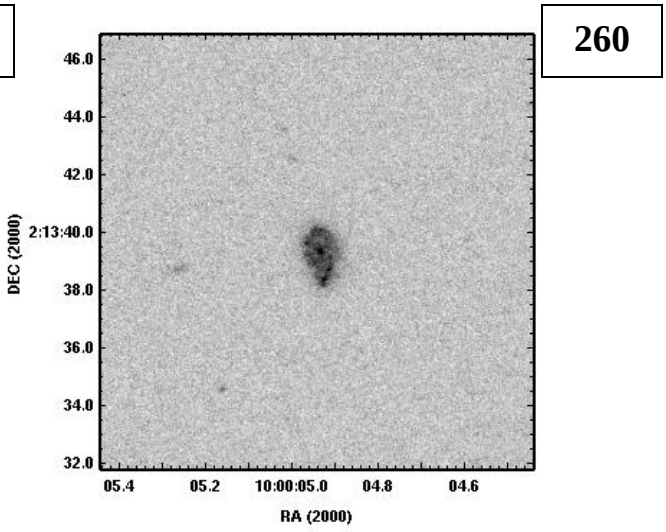
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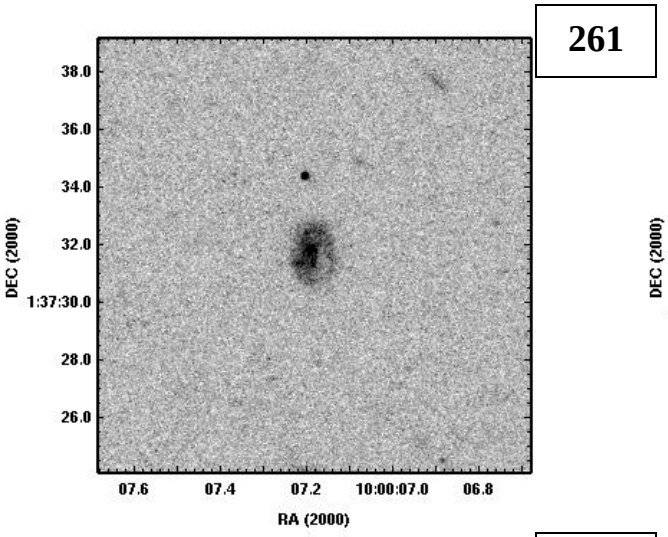
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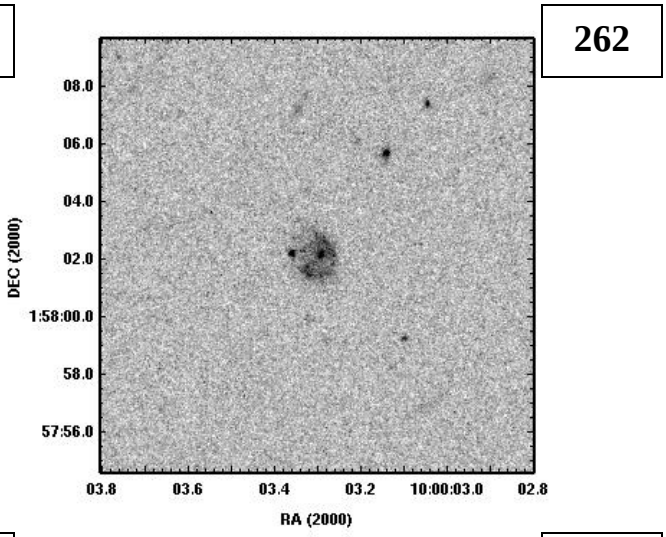
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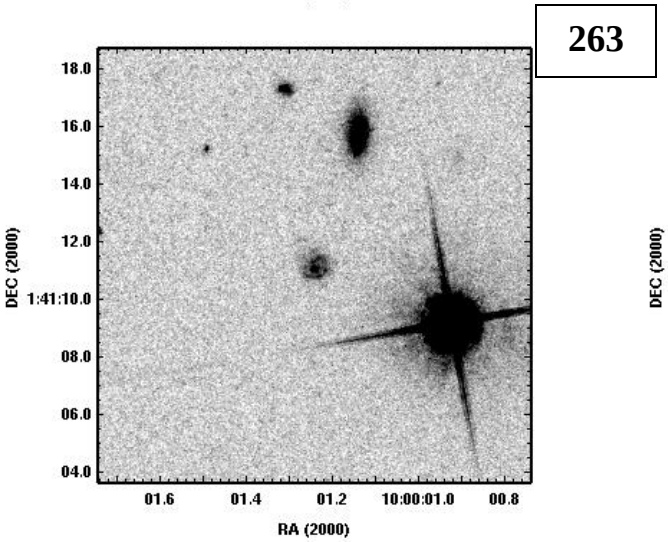
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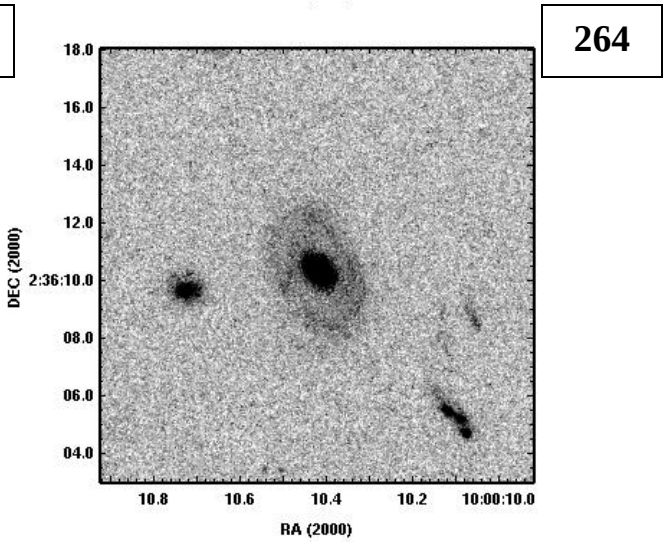
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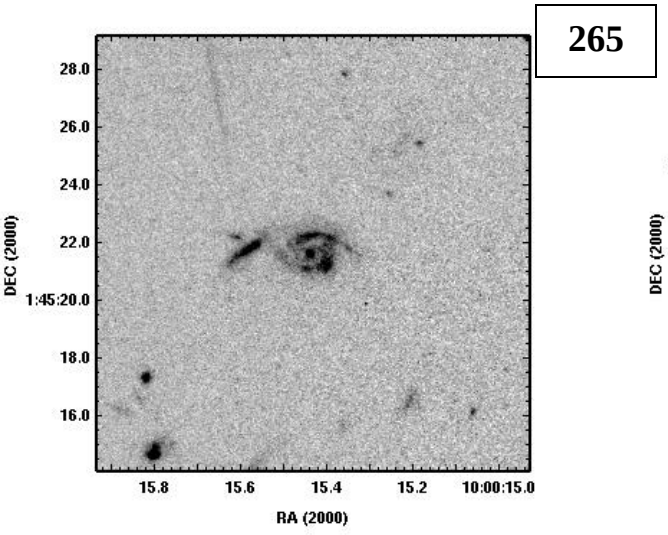
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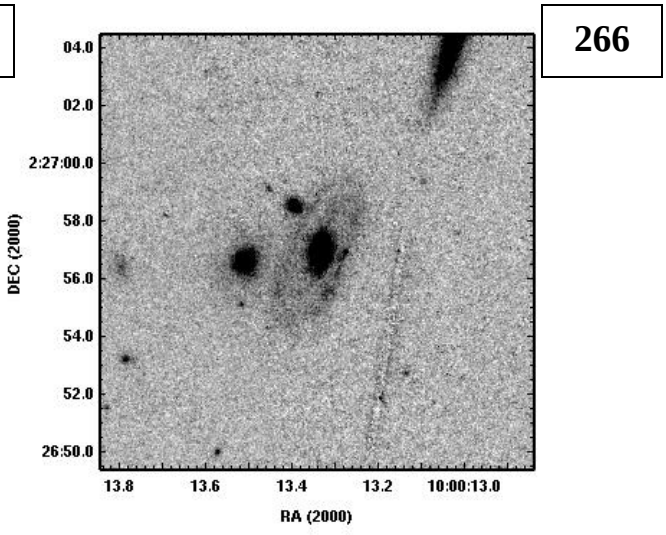
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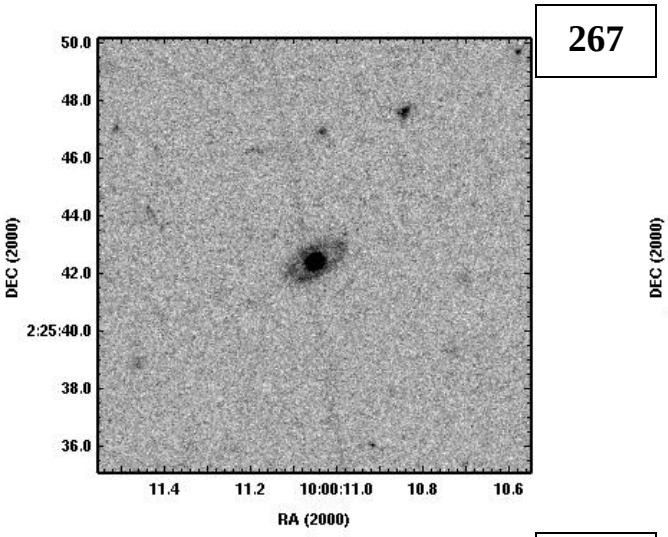
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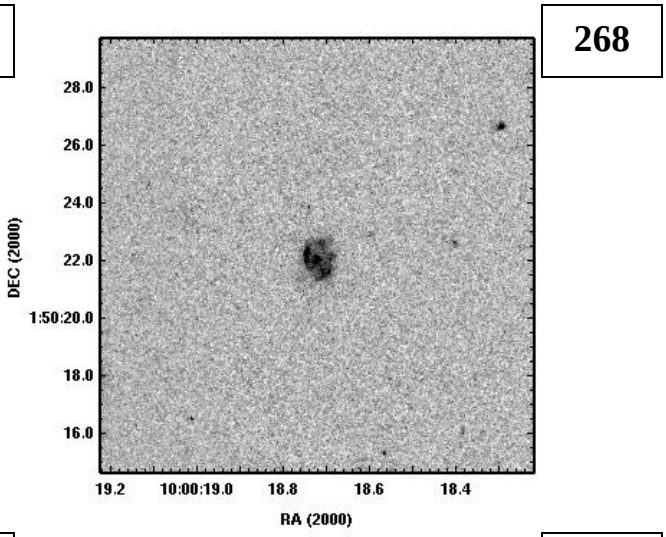
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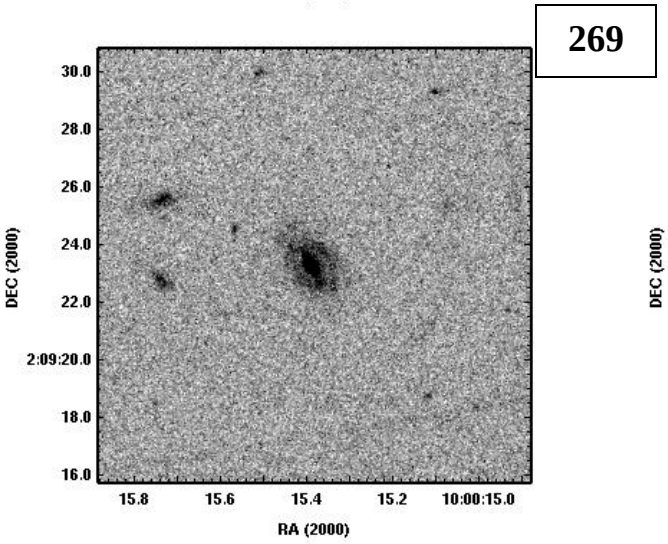
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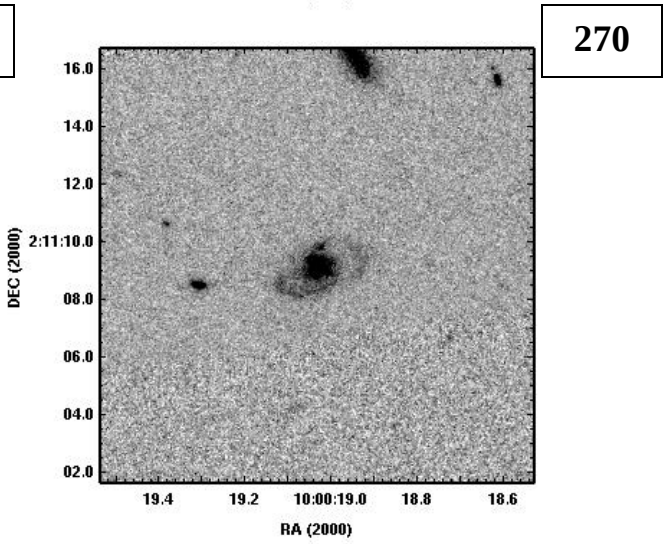
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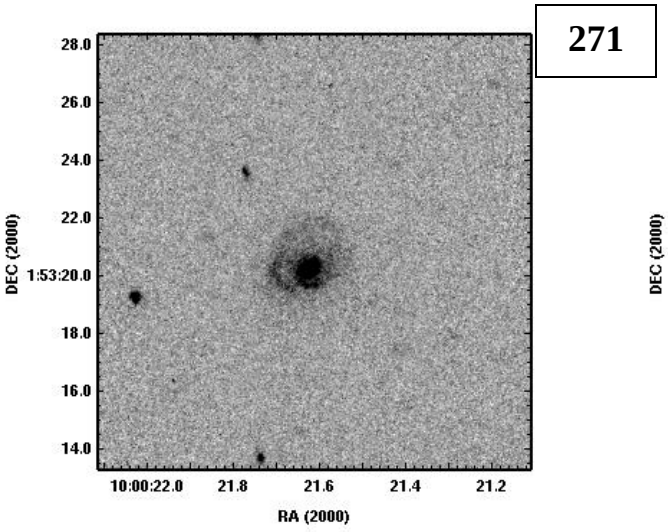
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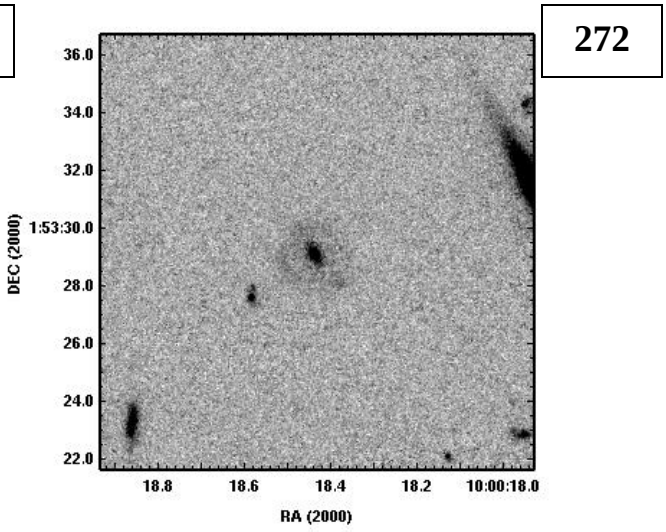
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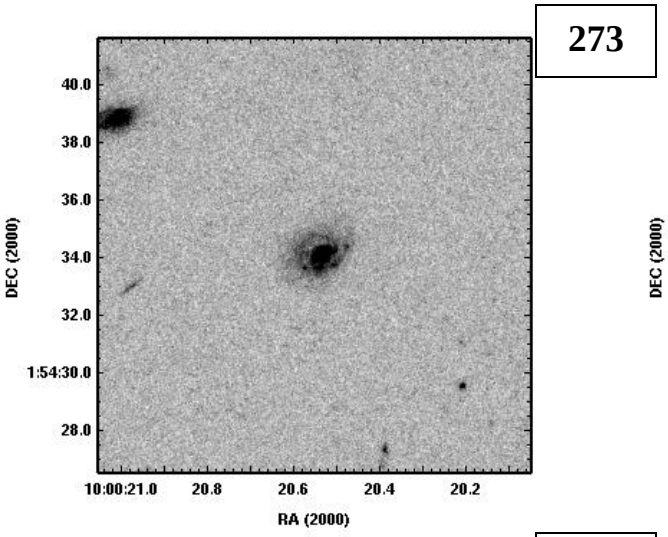
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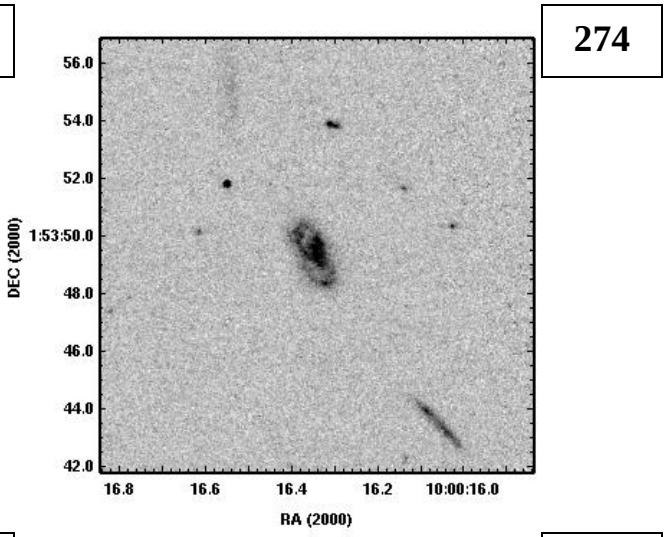
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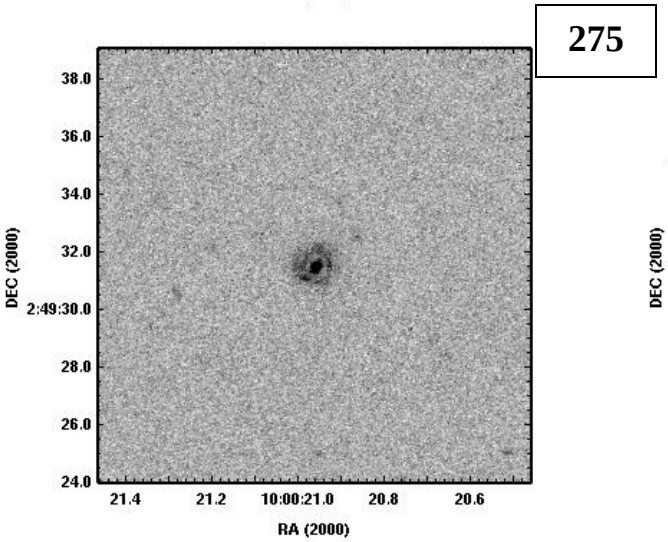
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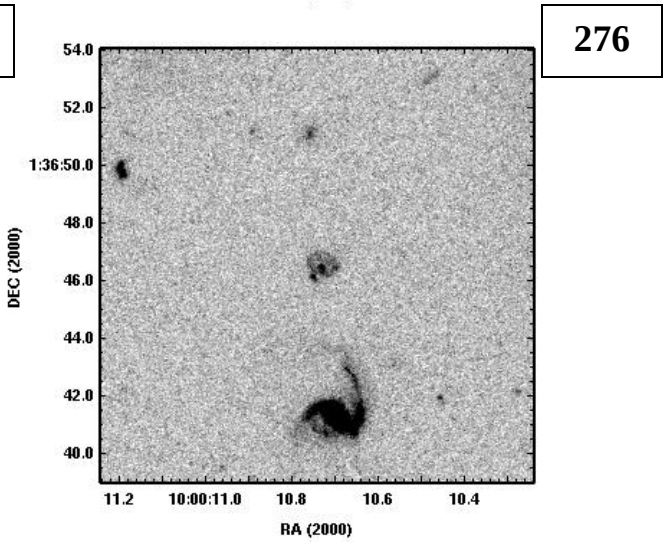
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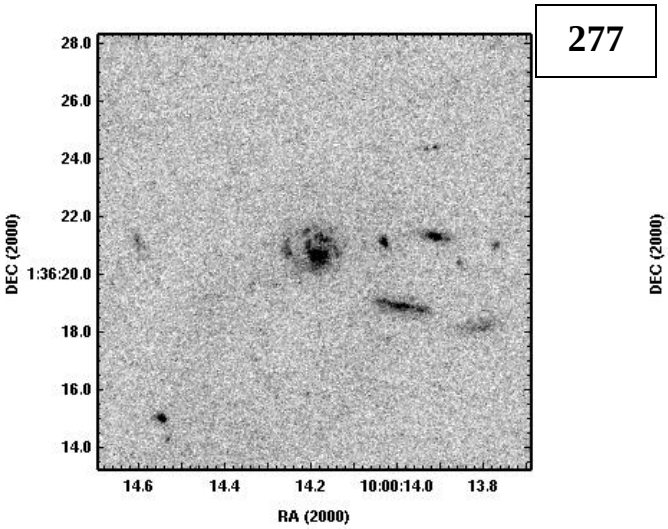
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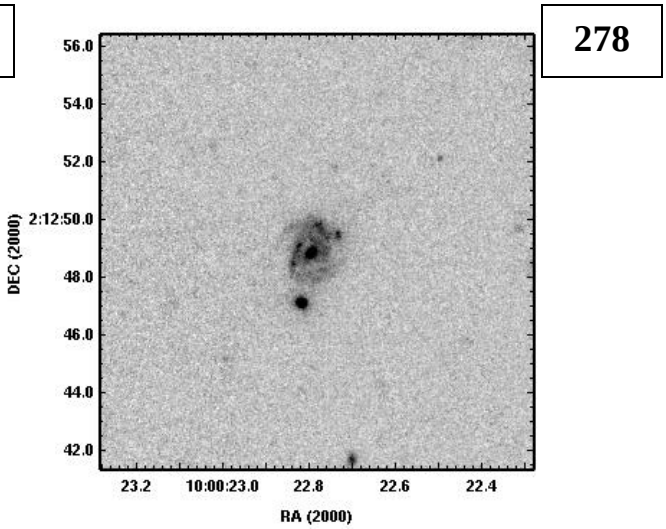
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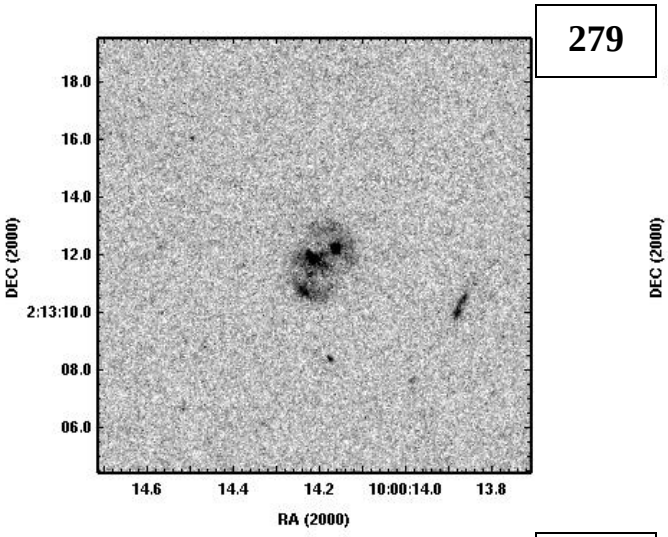
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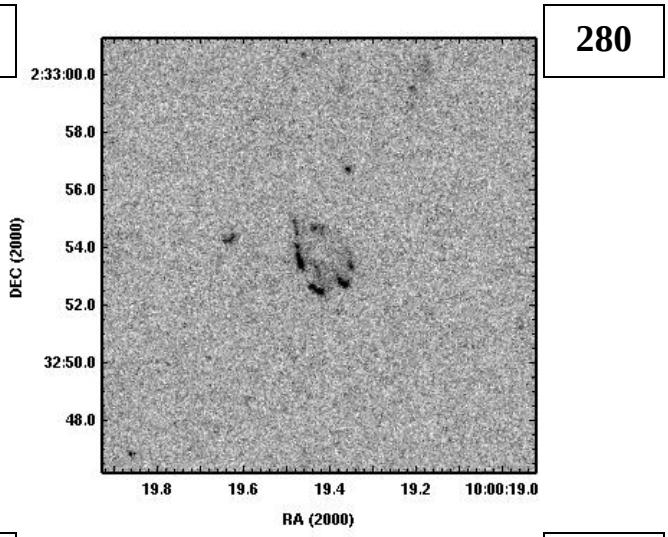
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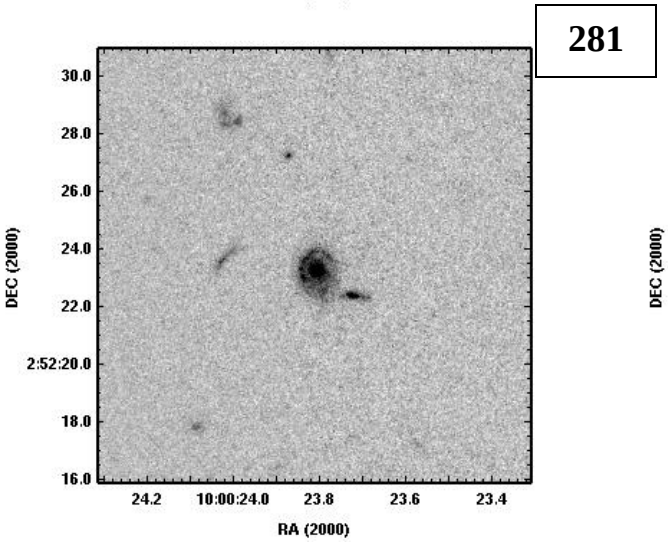
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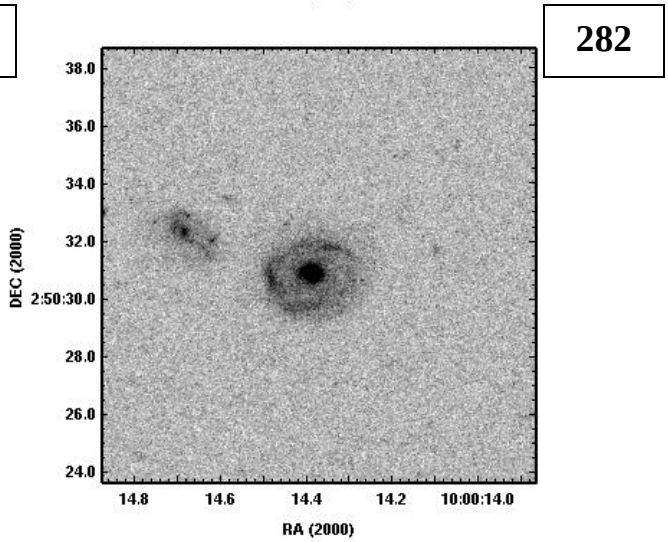
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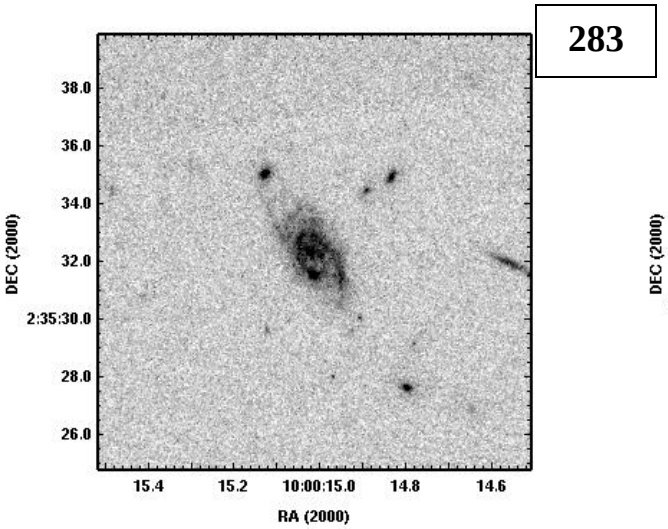
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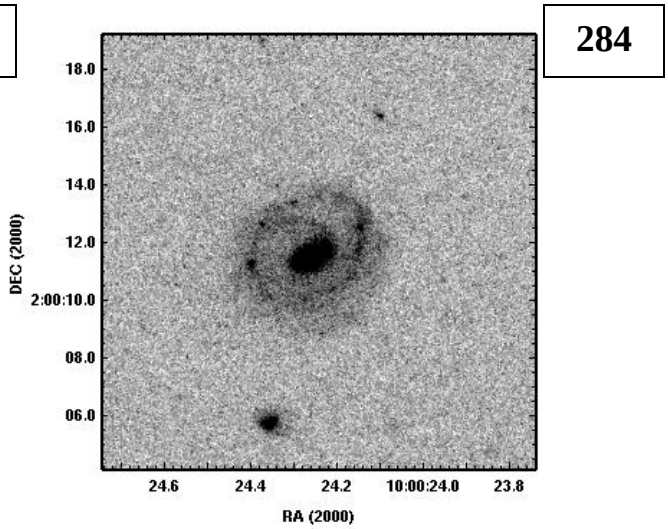
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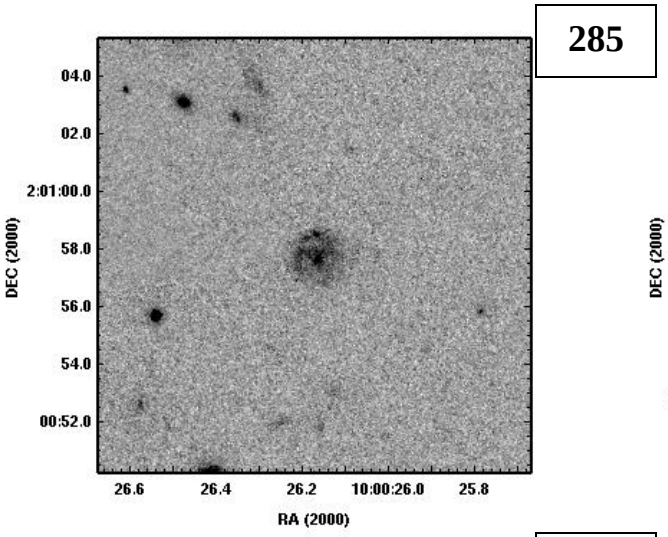
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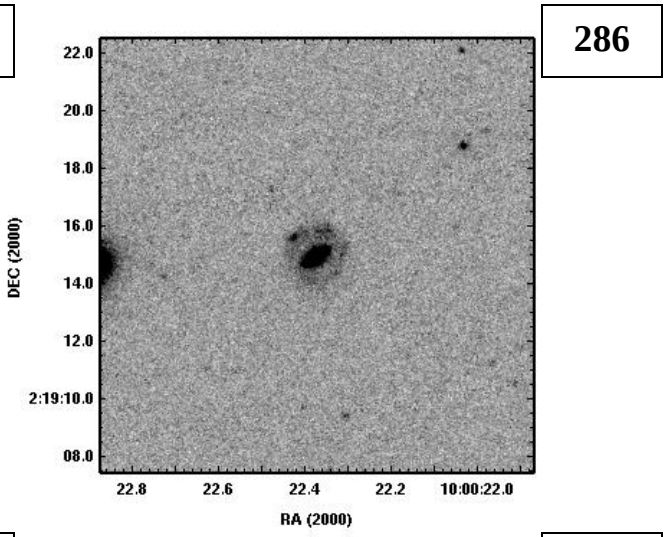
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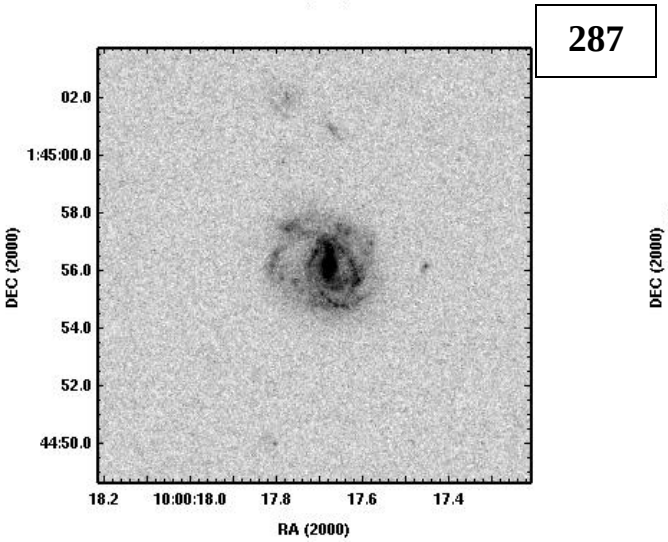
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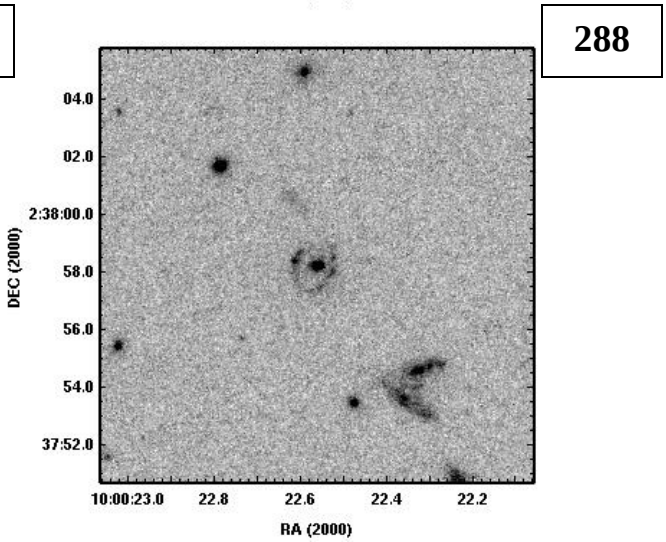
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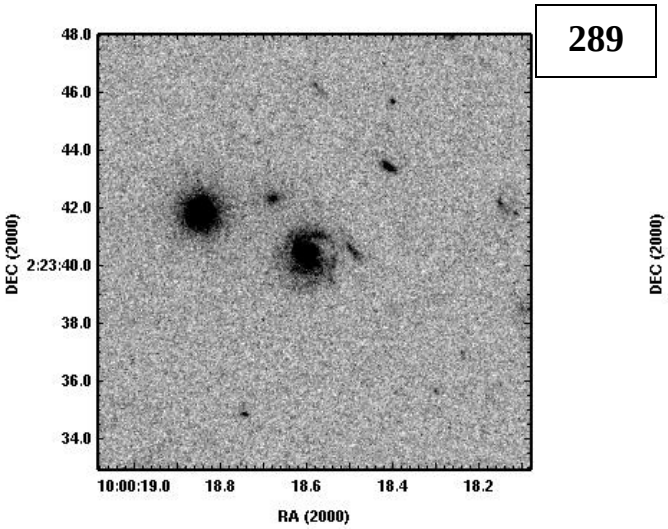
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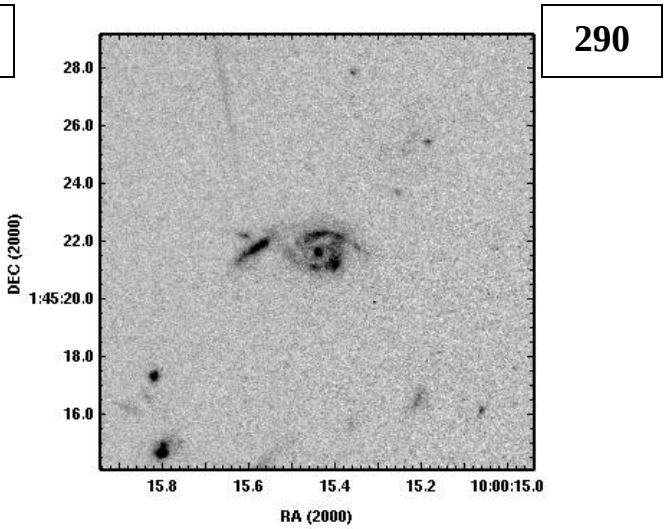
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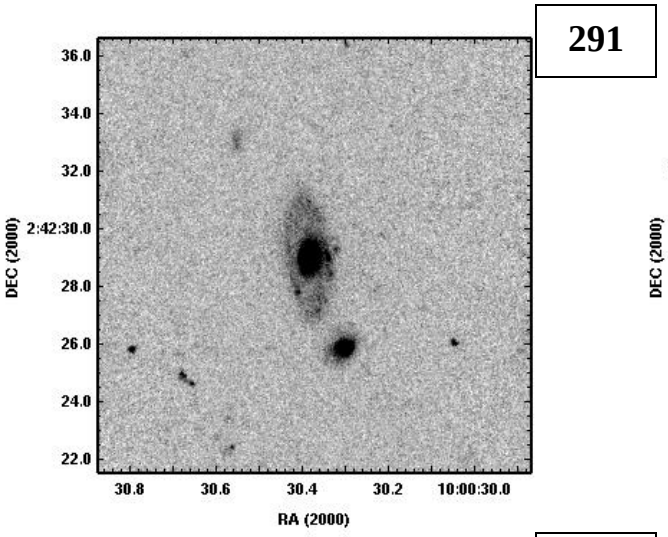
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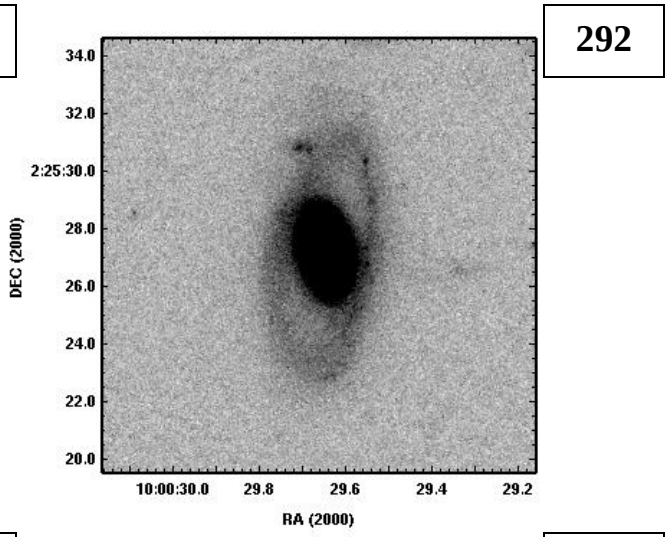
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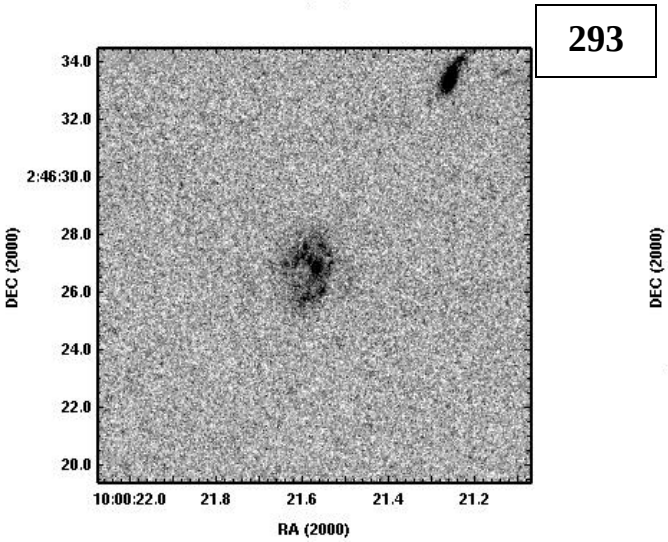
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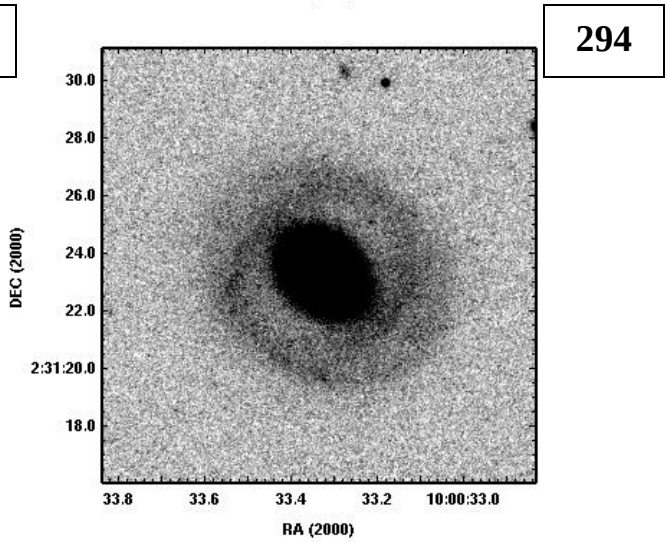
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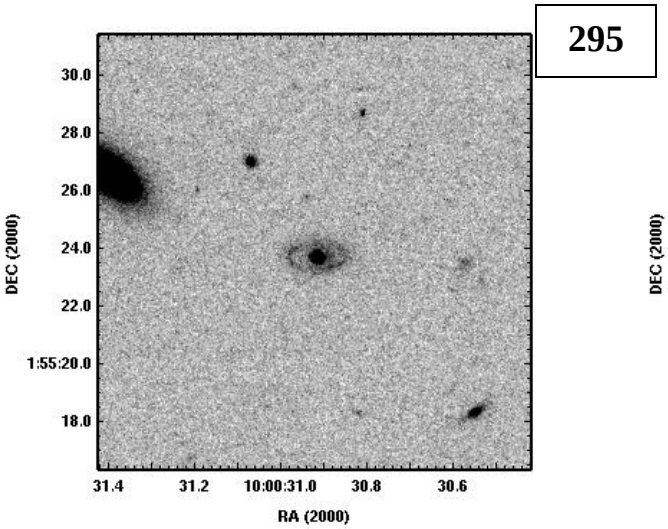
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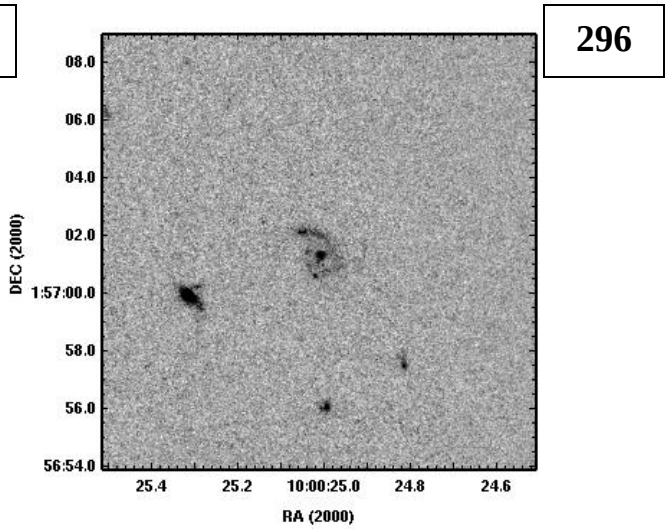
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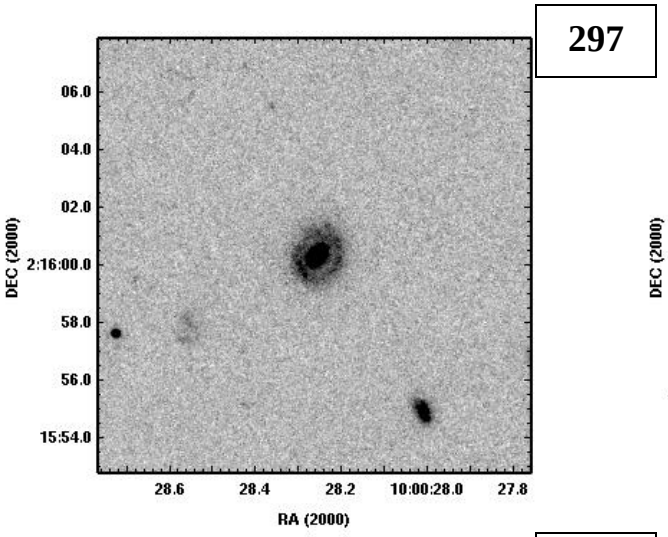
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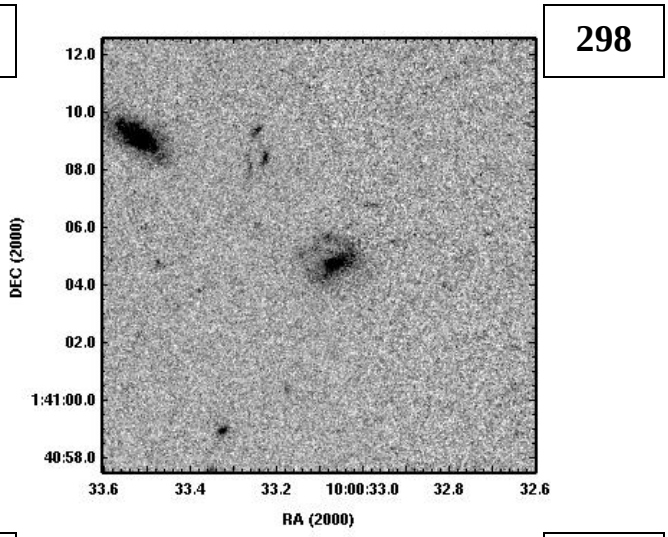
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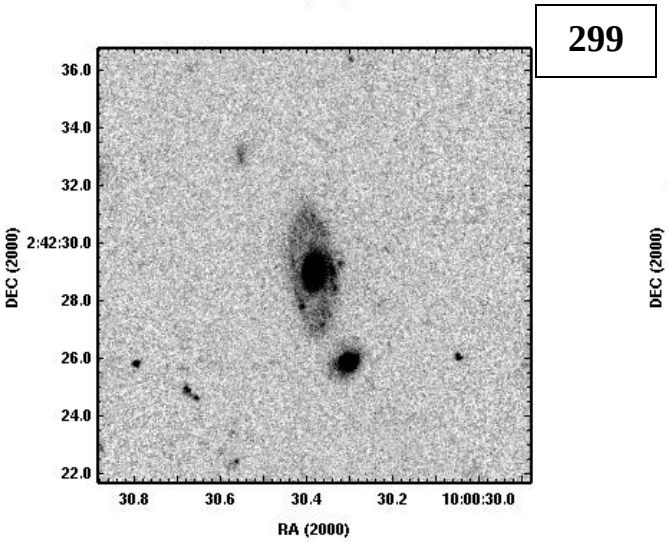
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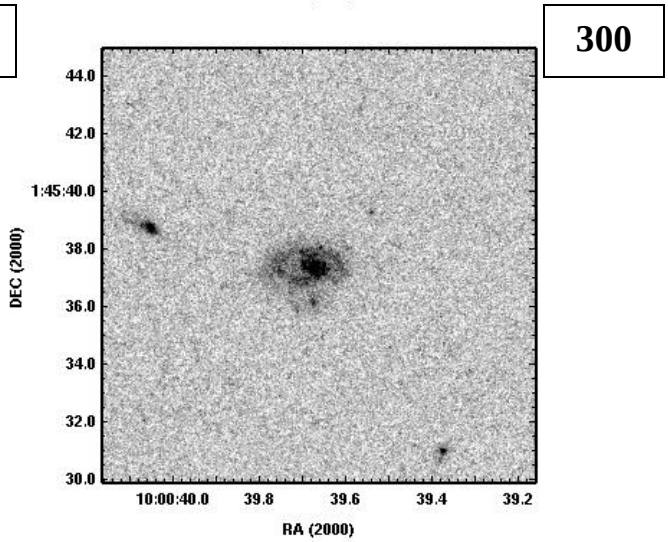
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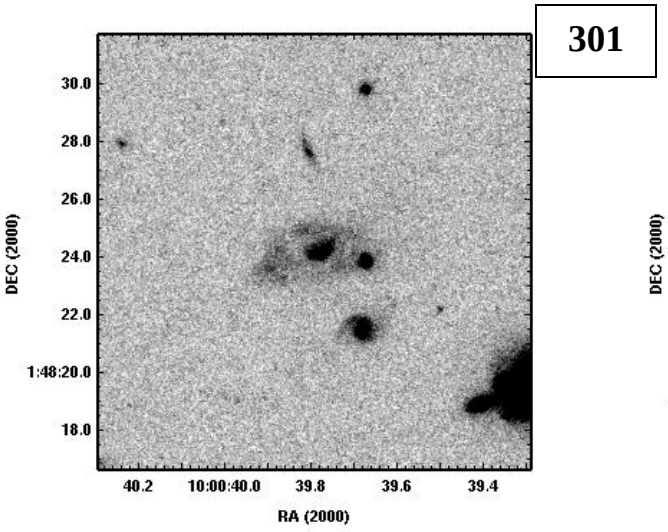
RA (2000)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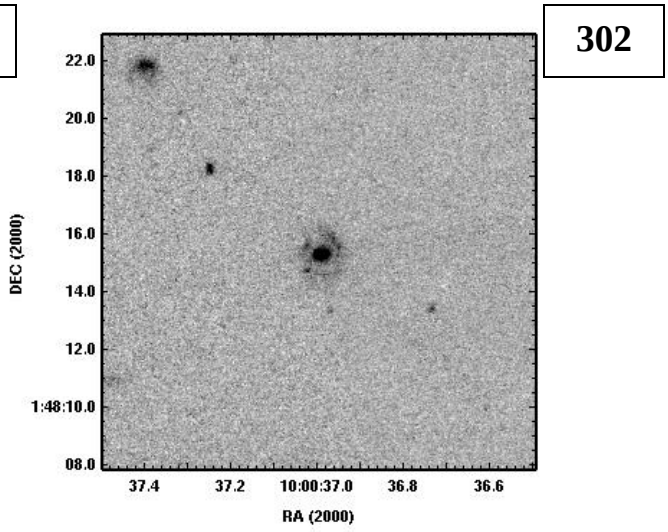
RA (2000)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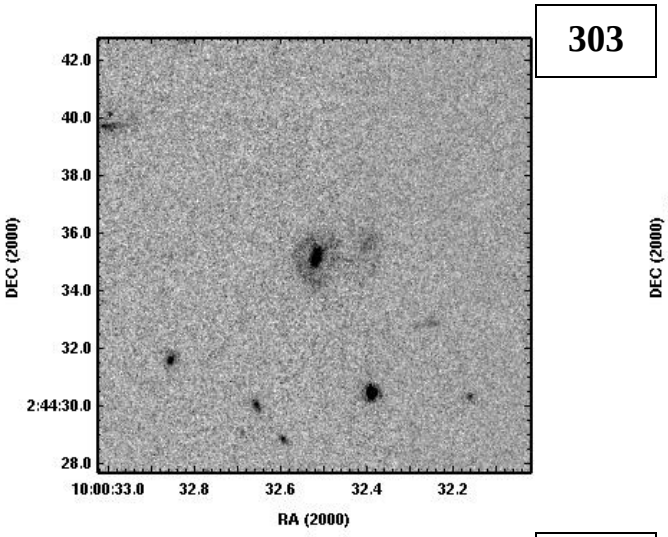
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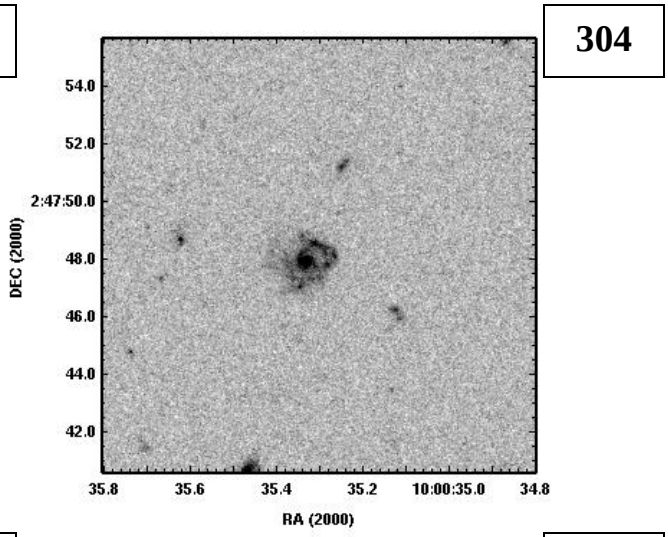
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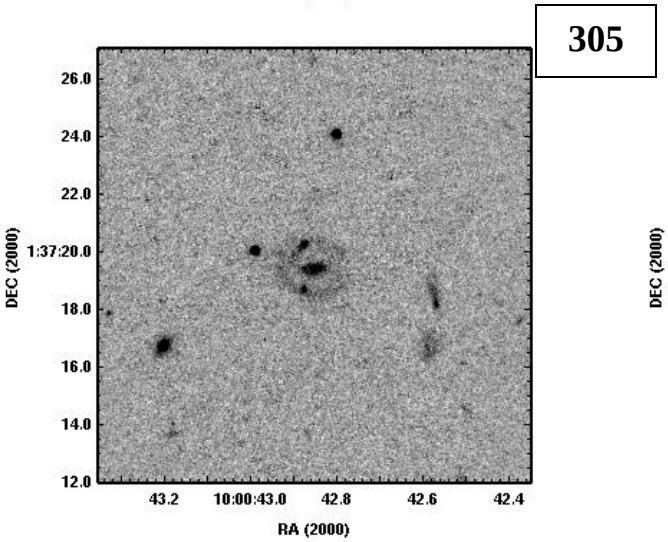
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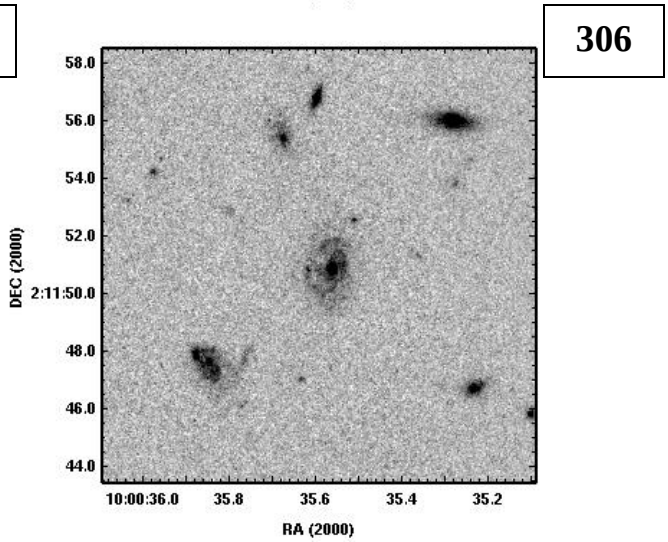
306
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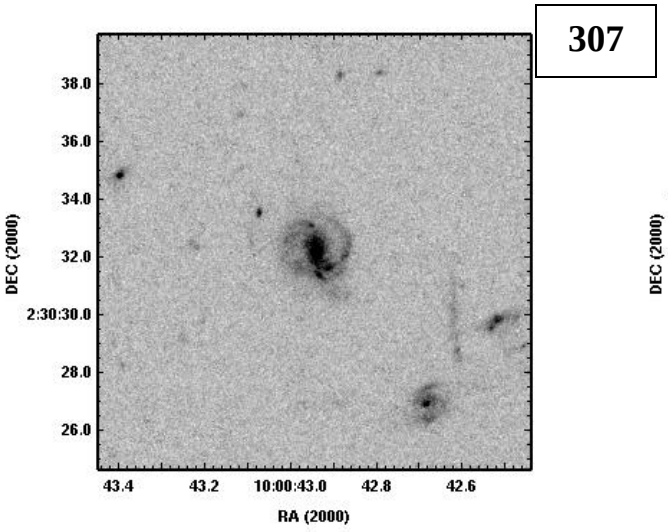
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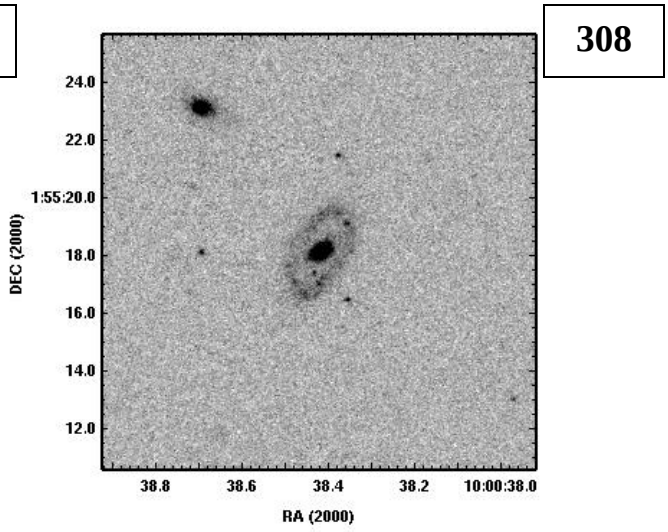
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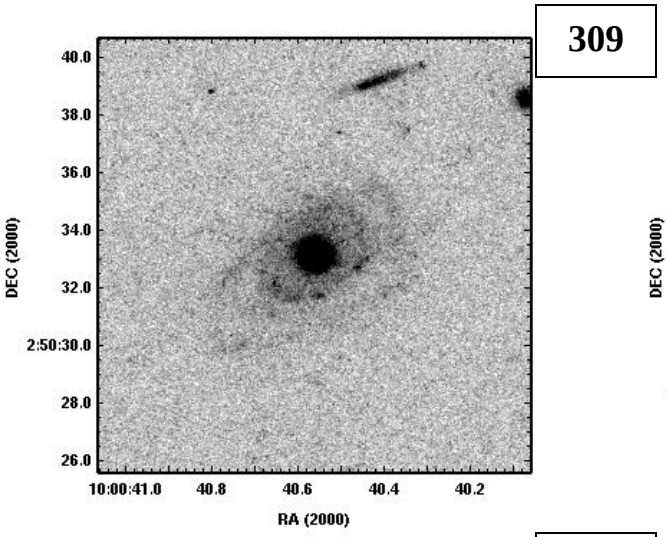
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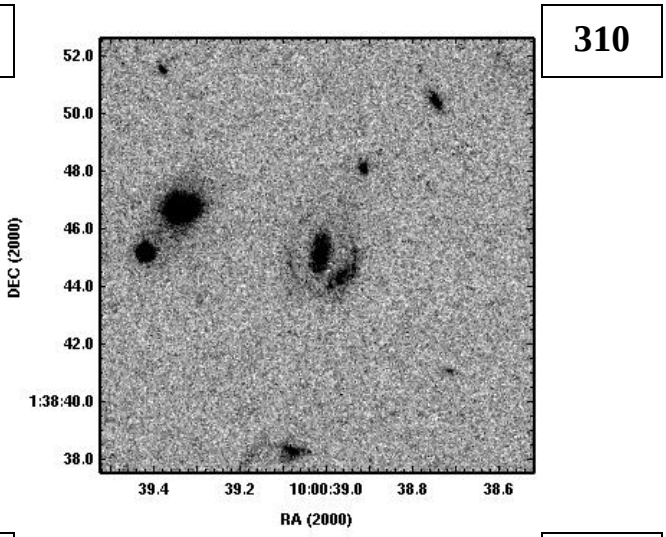
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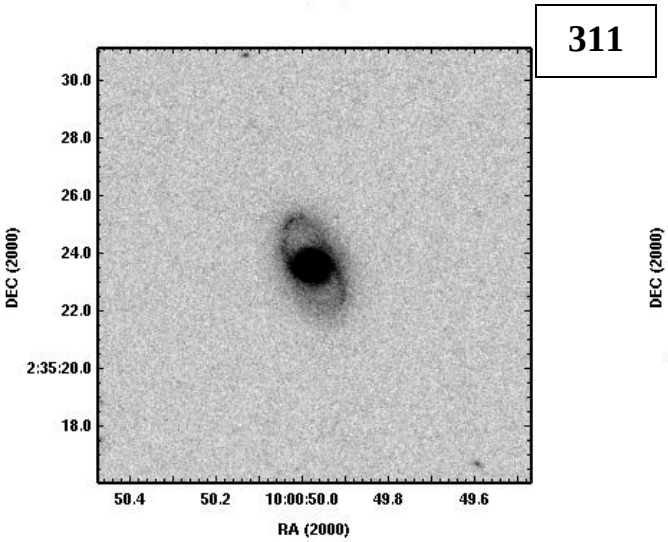
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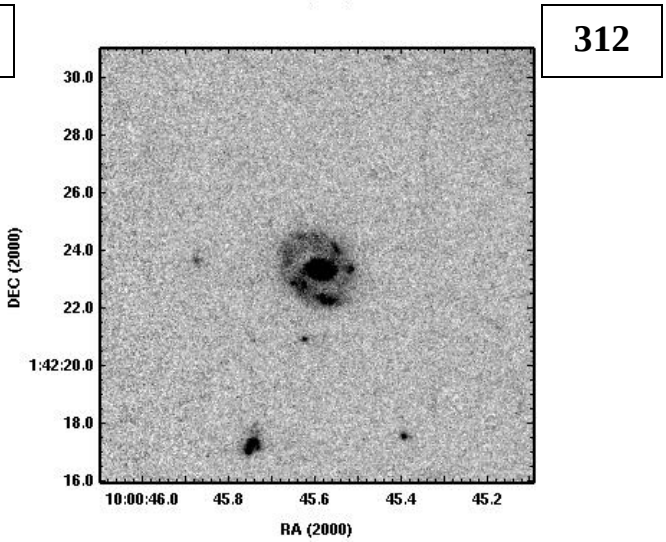
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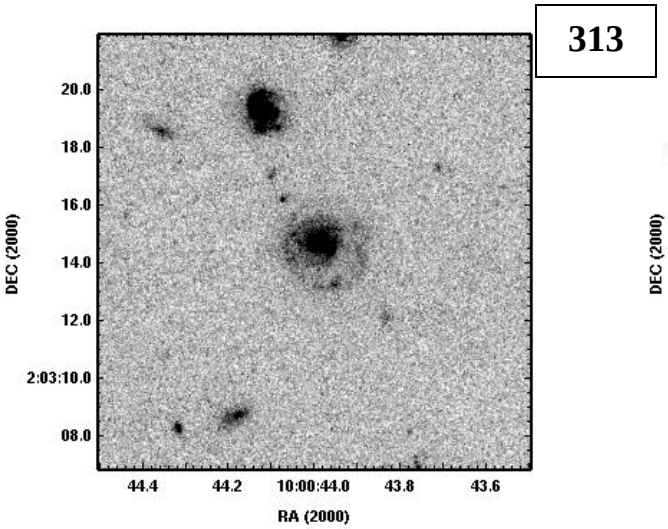
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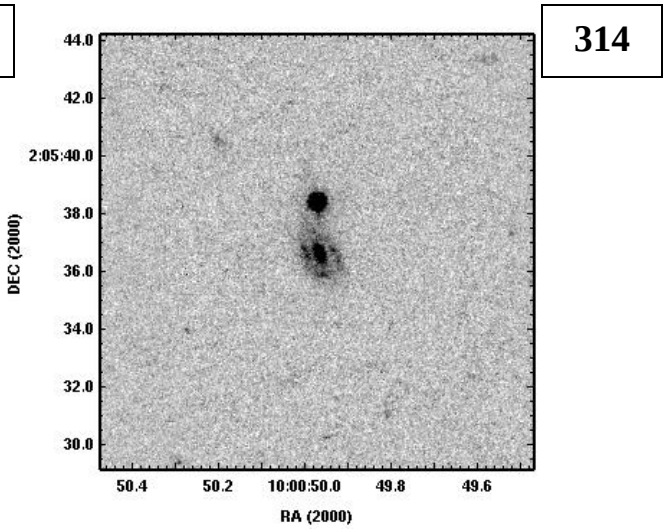
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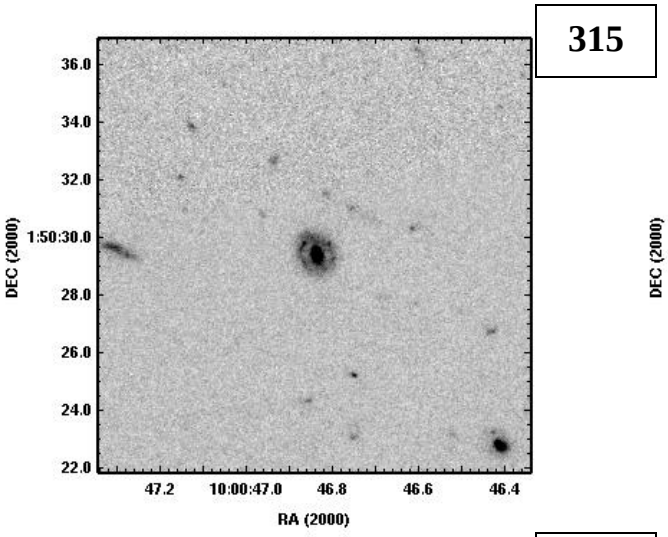
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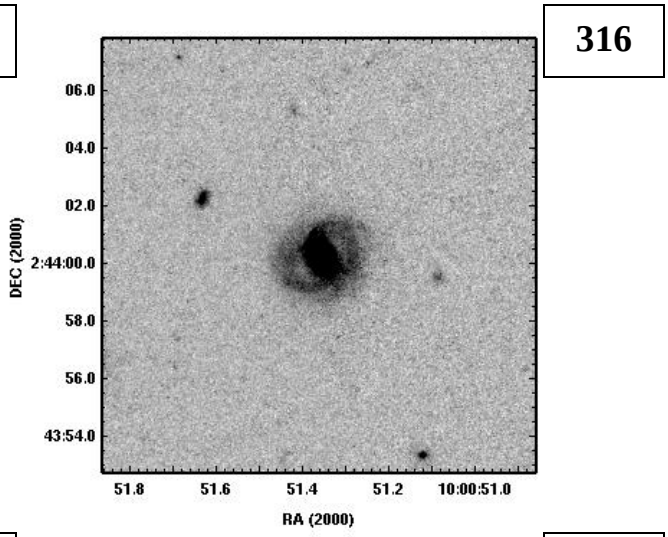
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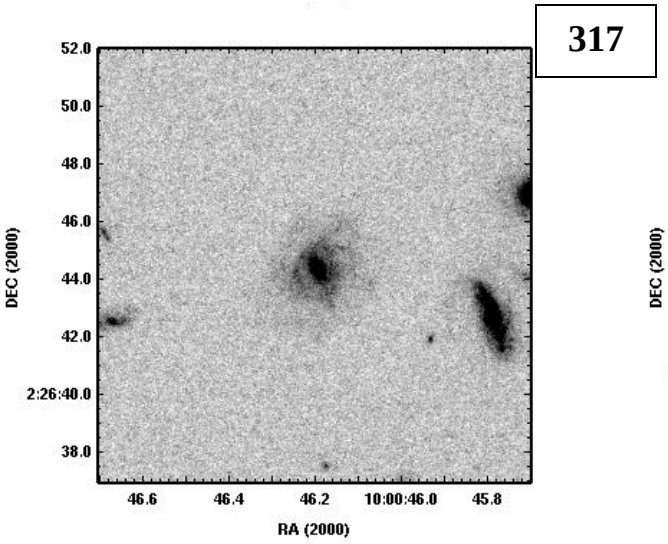
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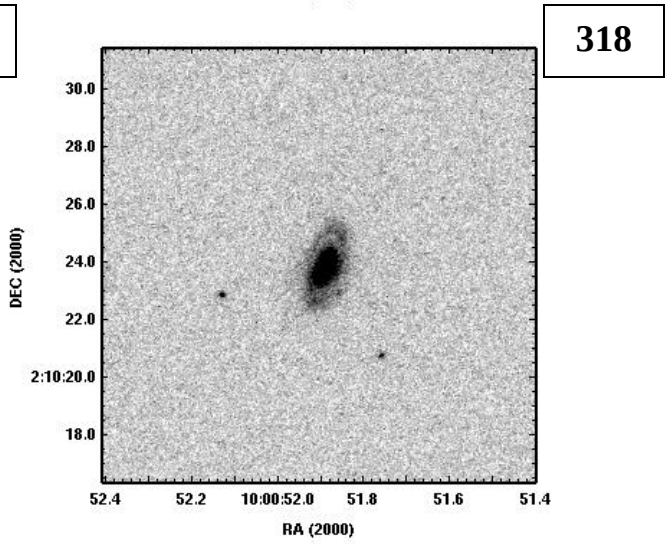
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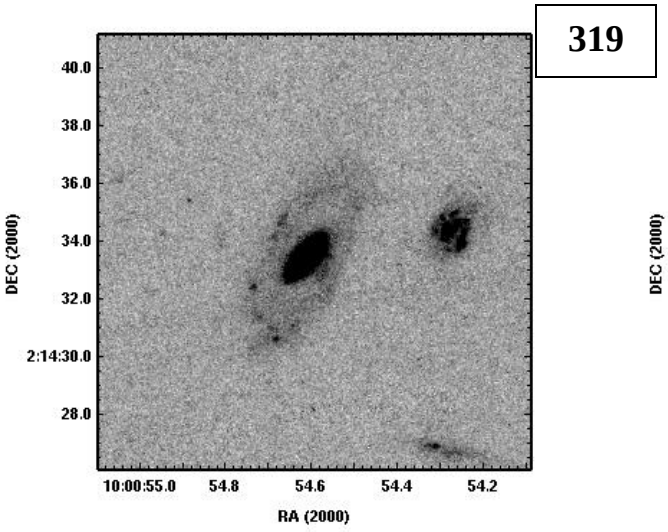
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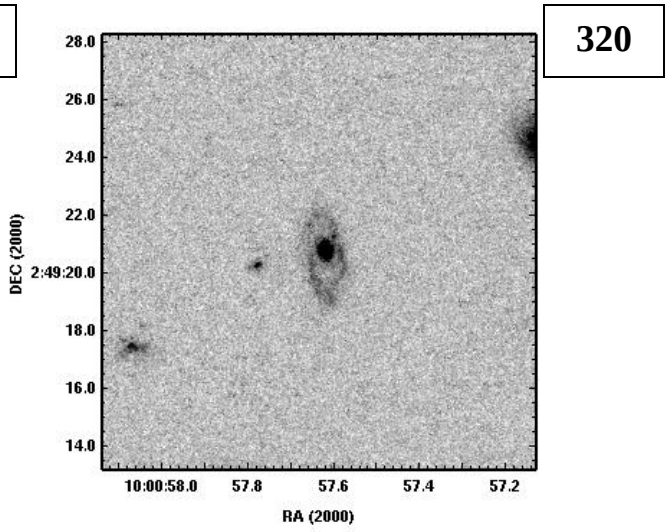
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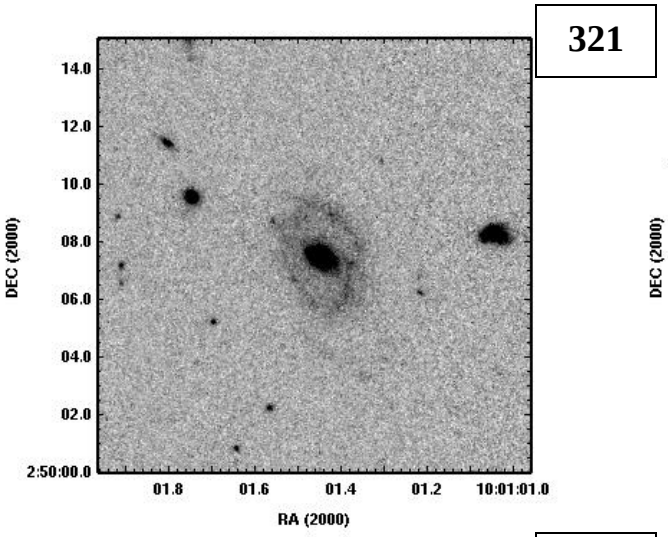
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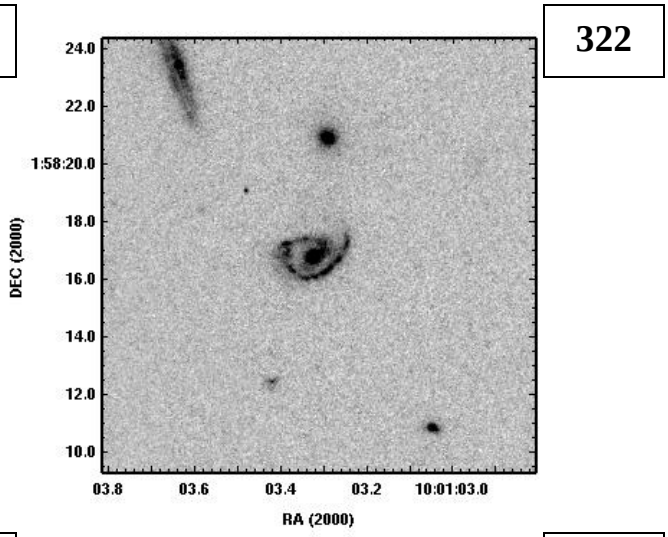
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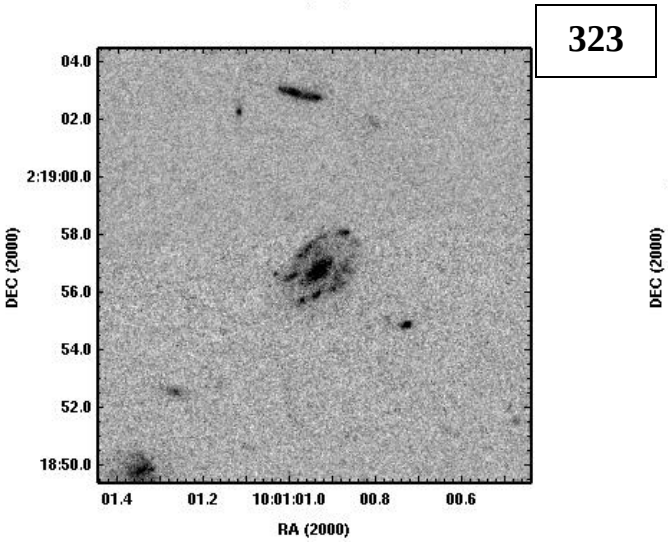
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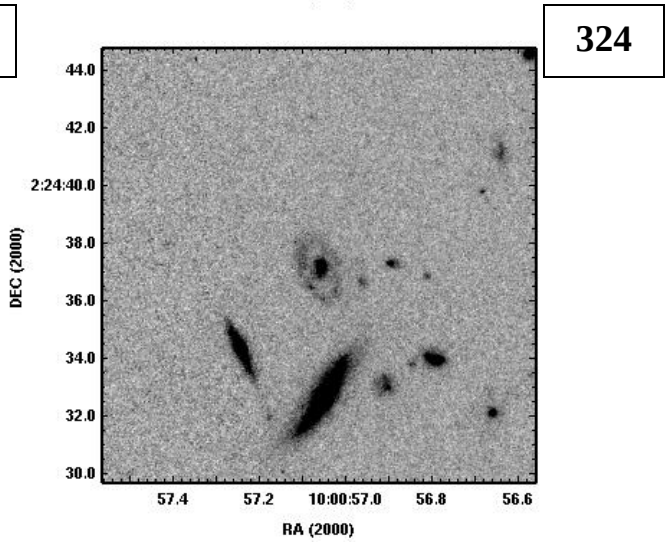
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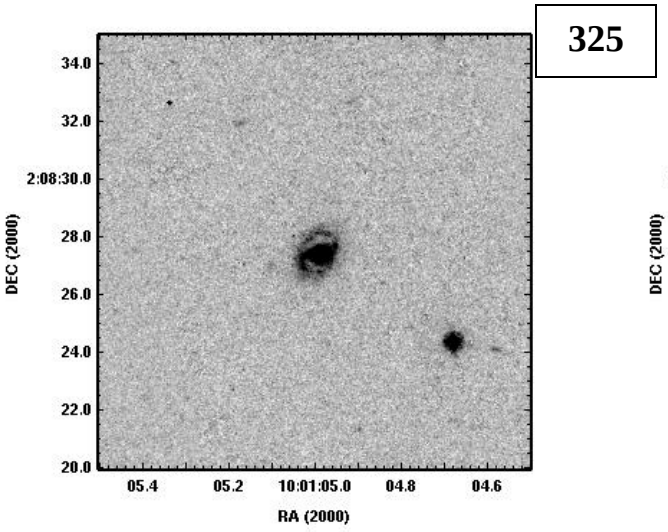
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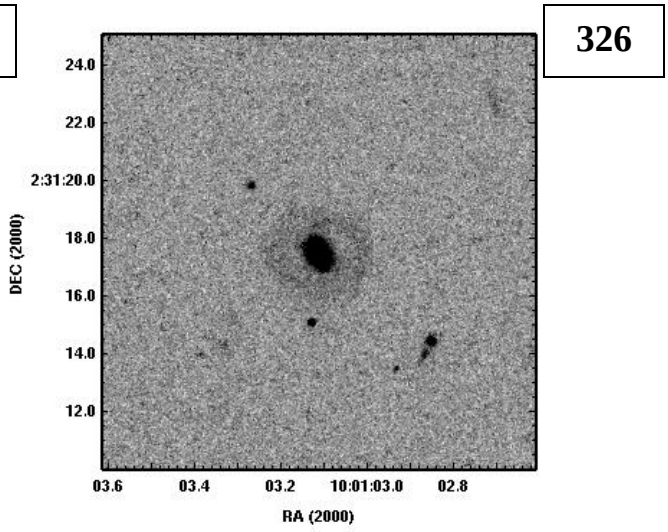
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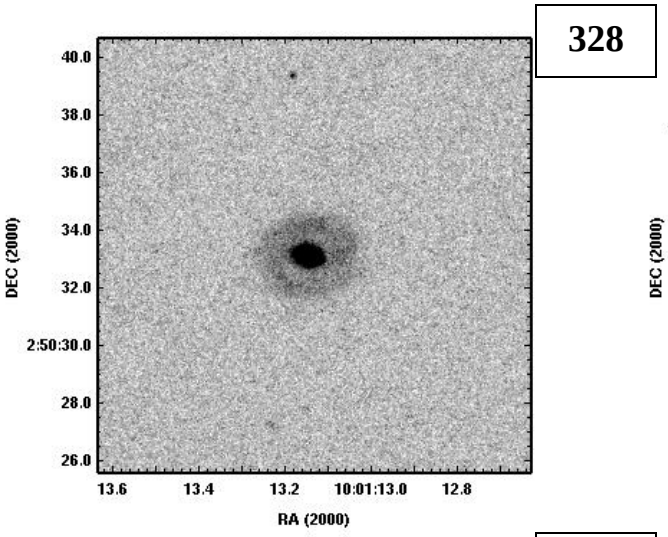
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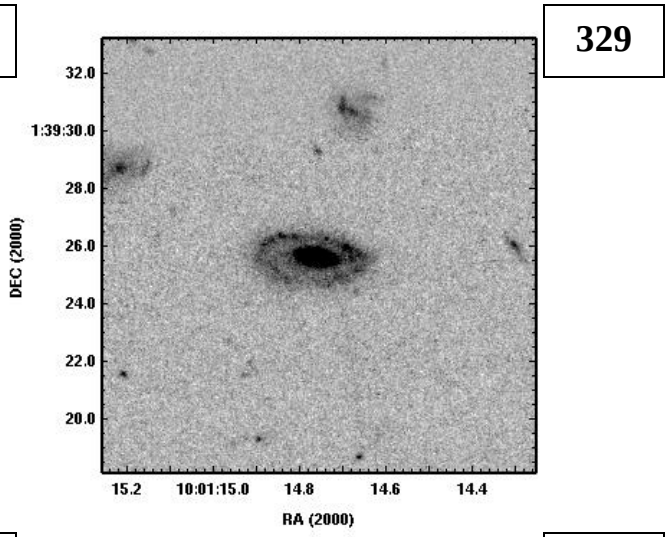
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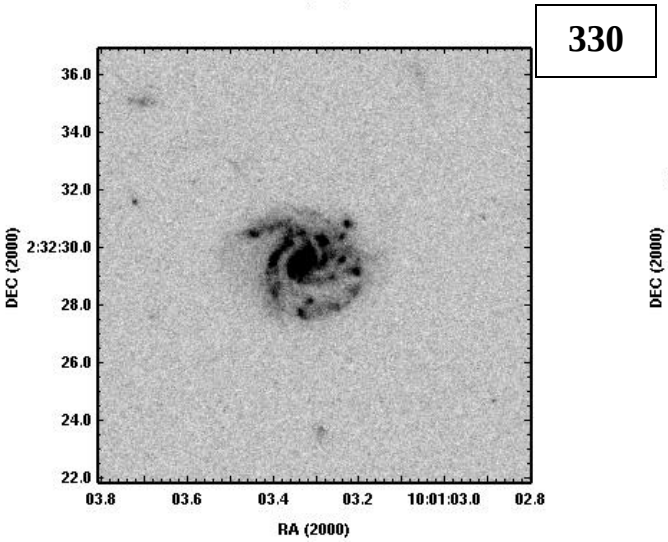
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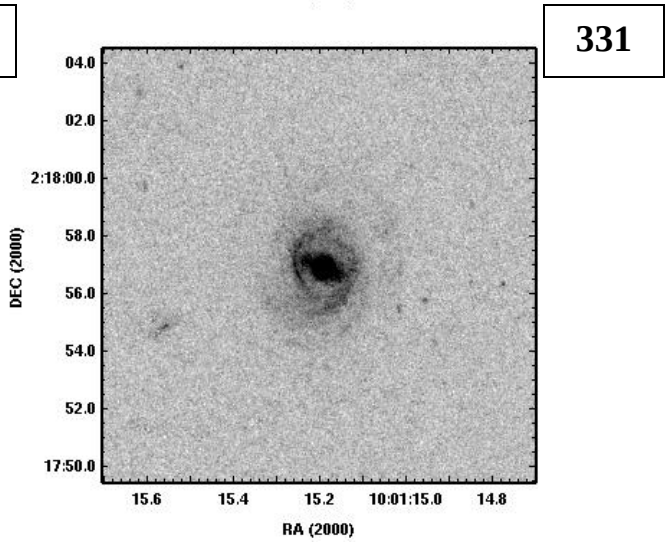
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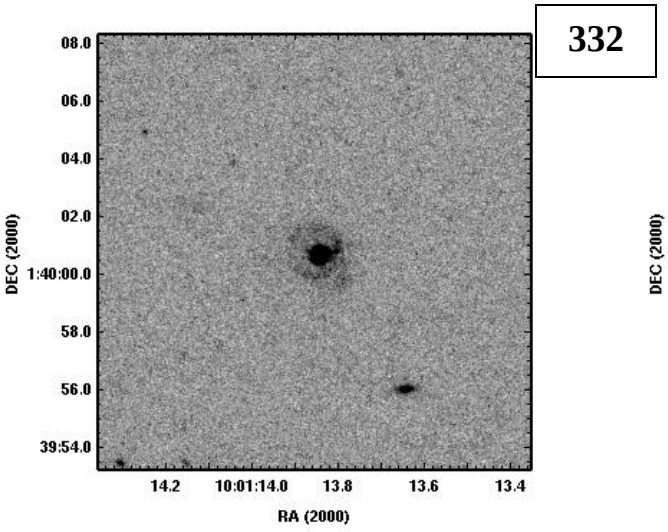
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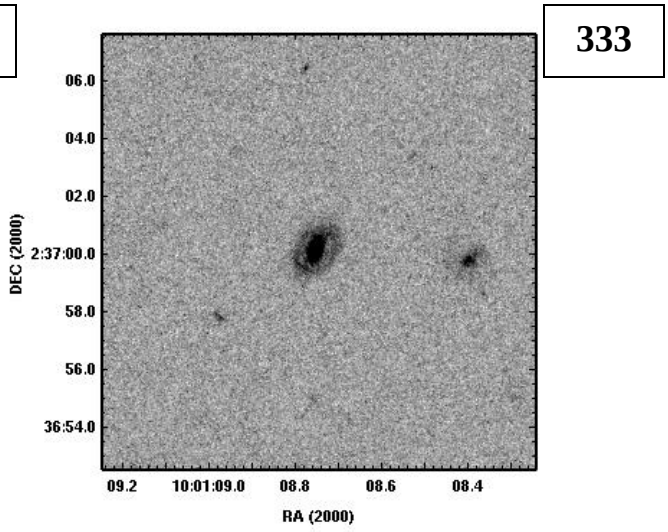
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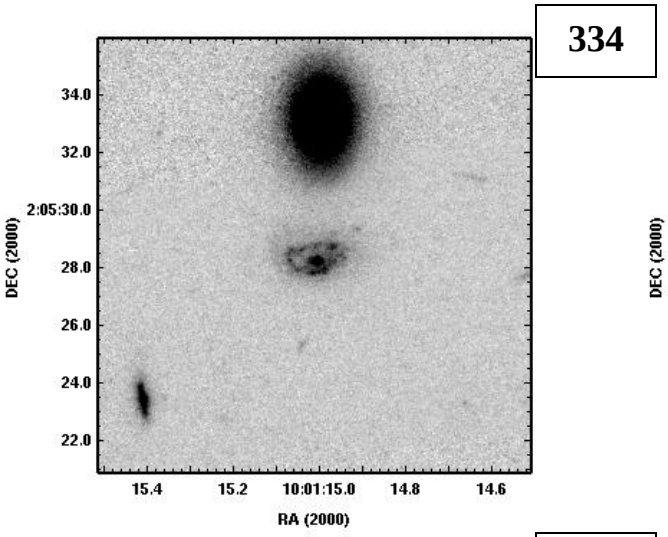
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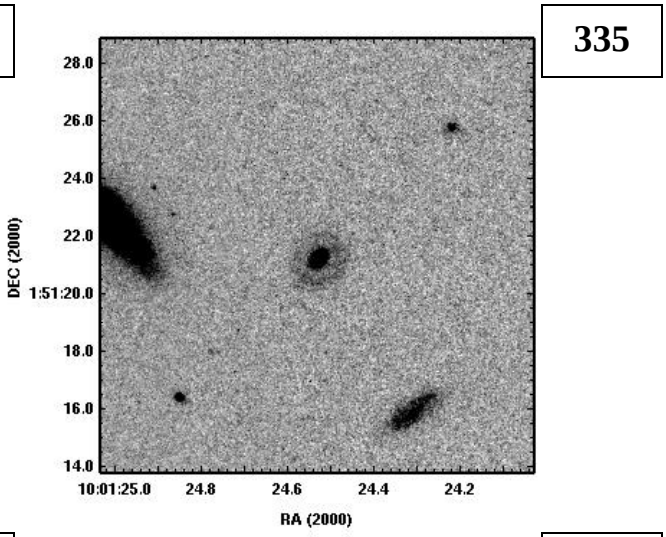
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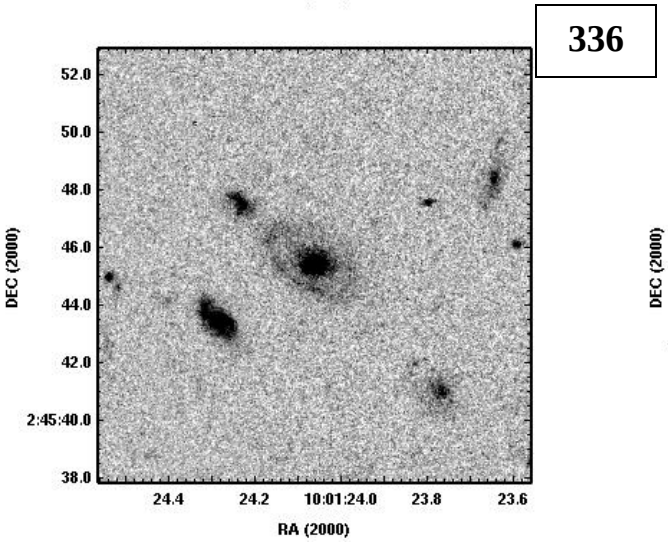
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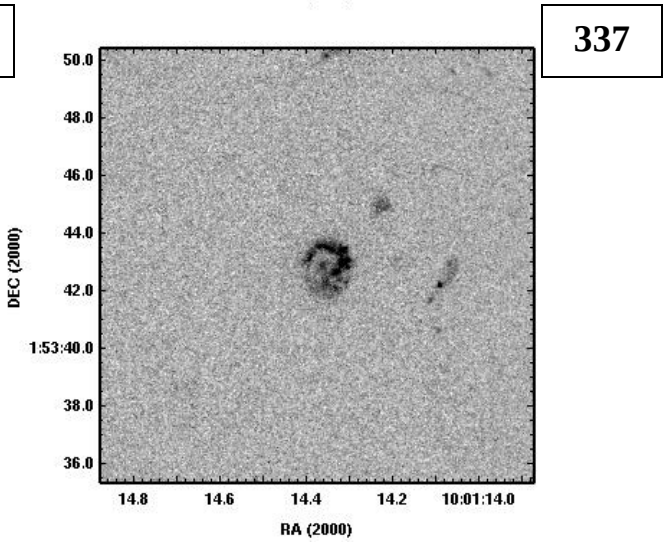
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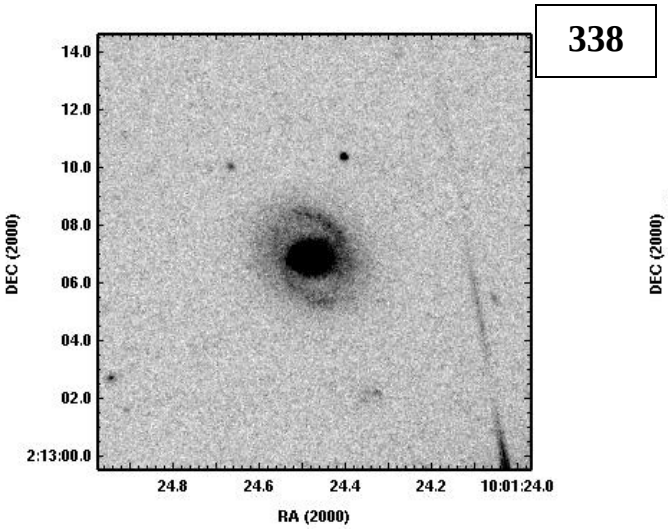
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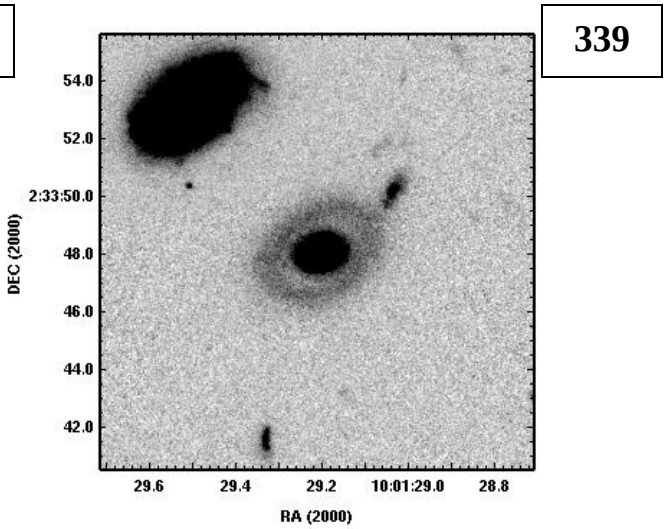
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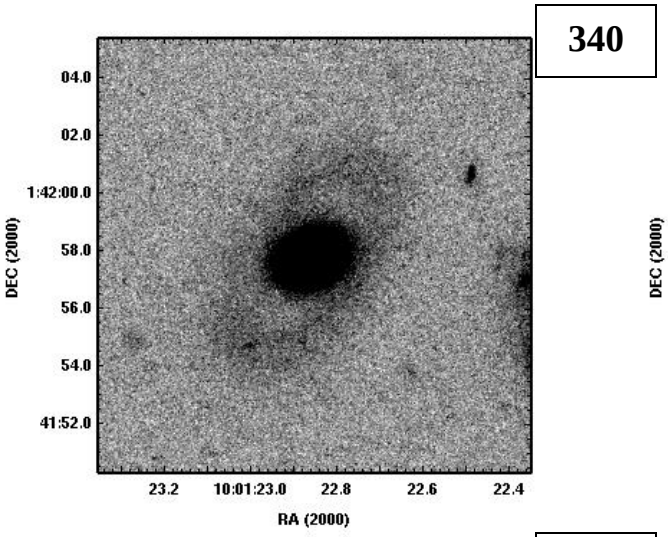
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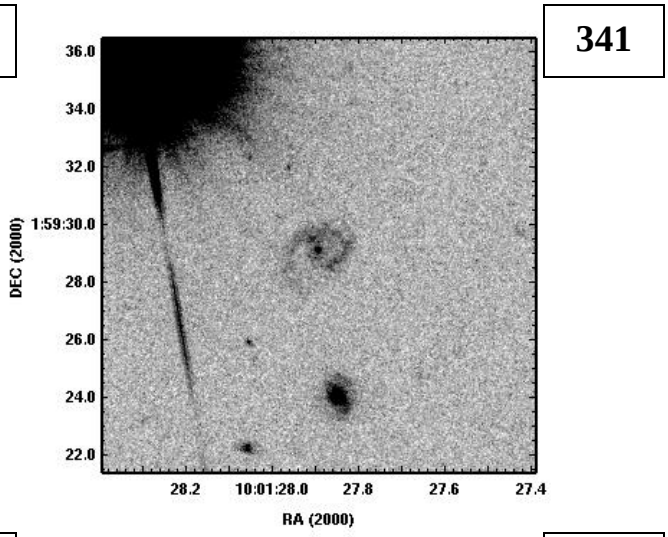
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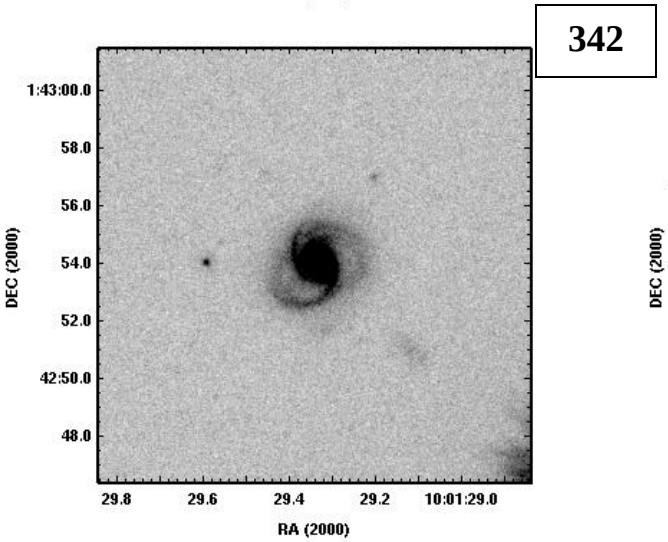
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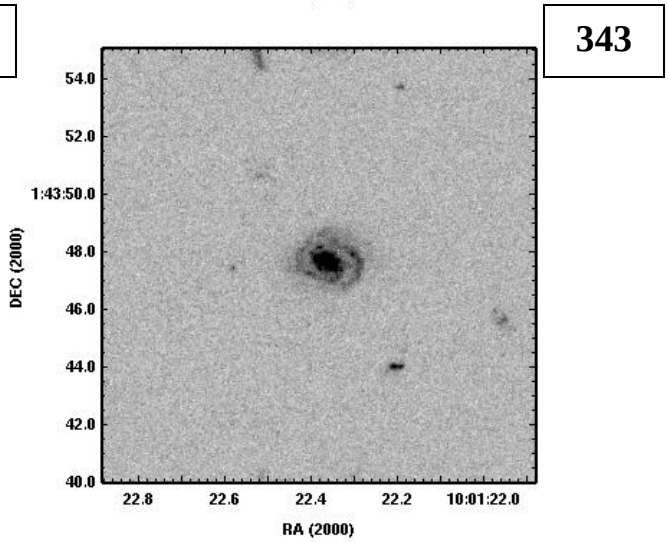
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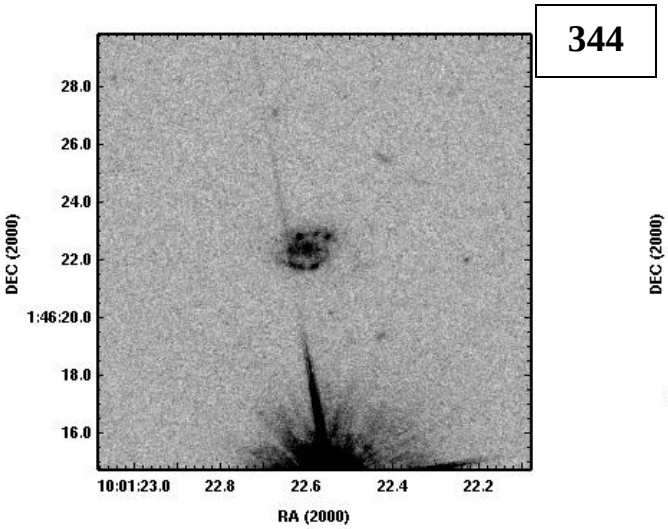
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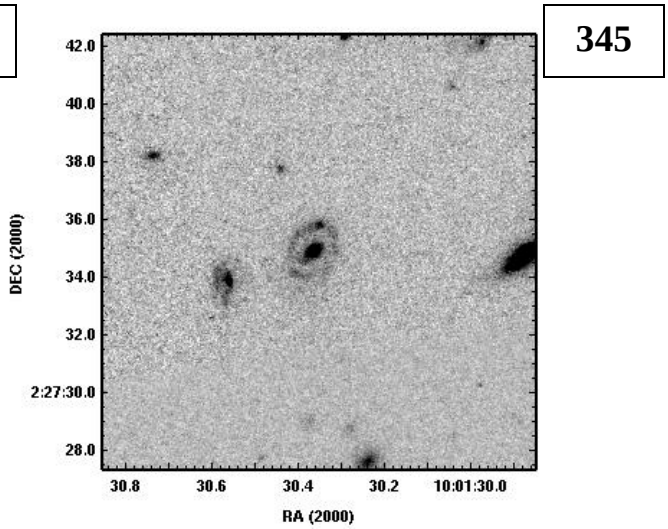
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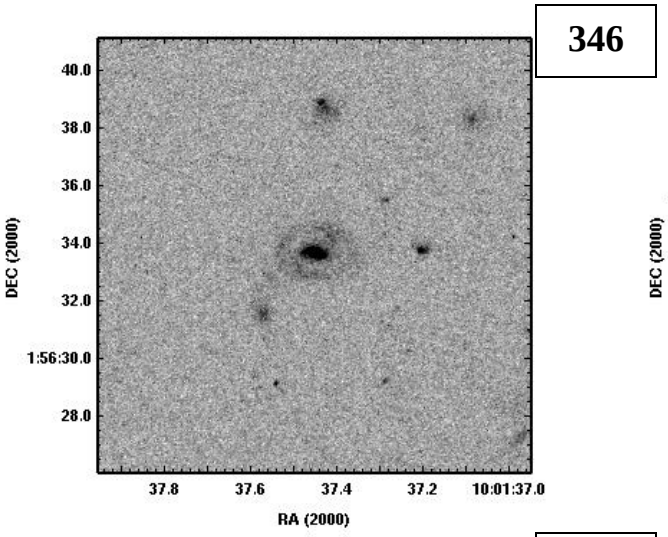
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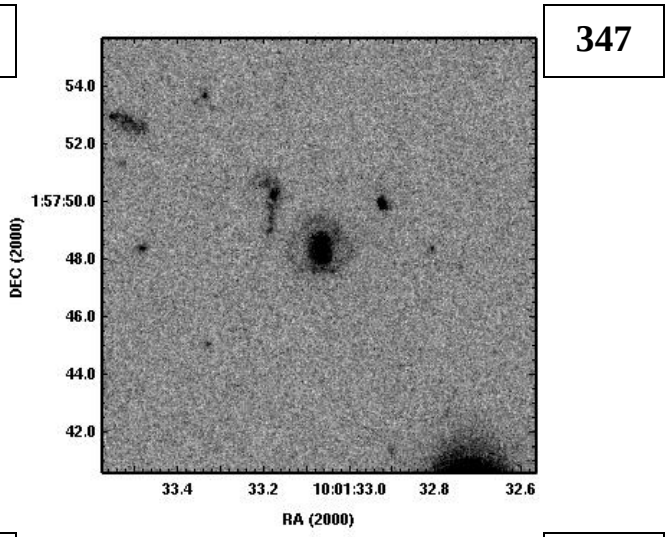
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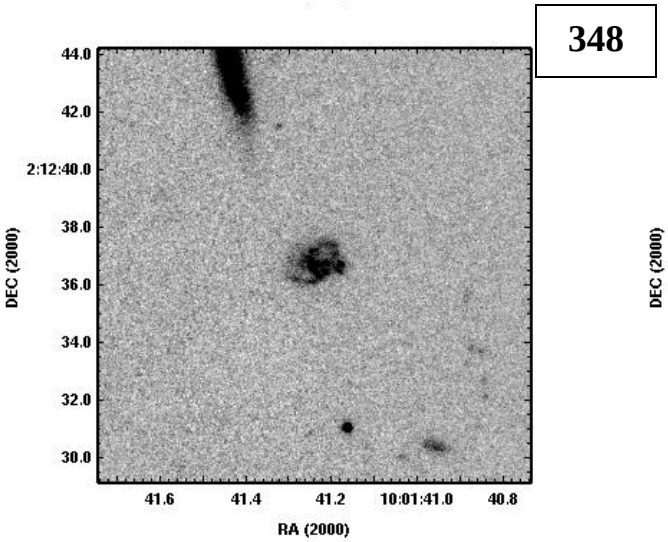
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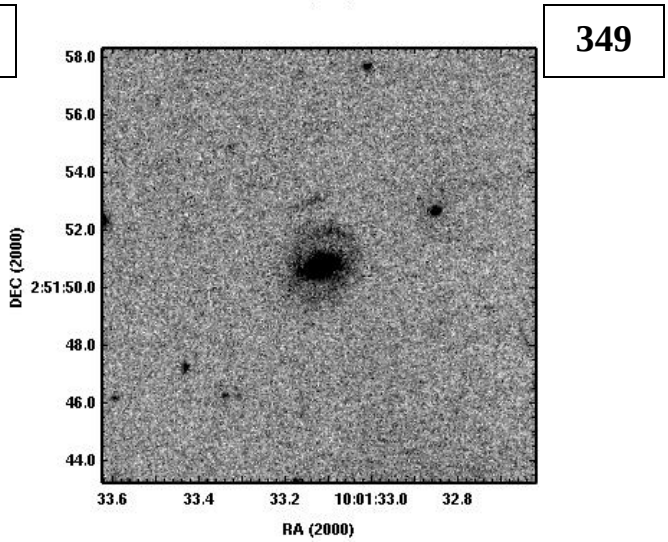
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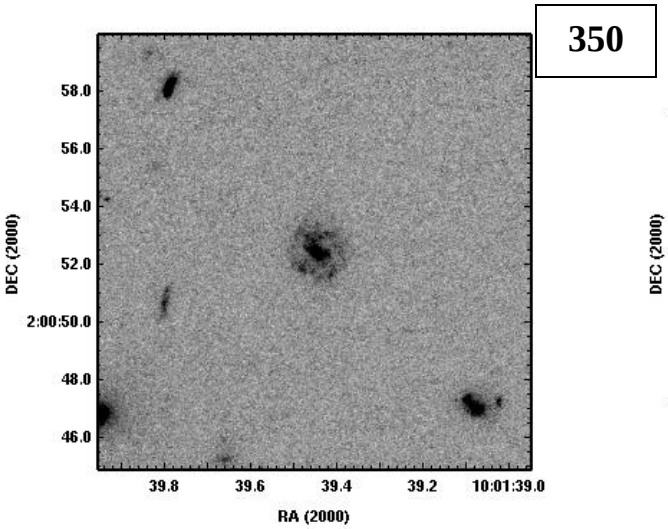
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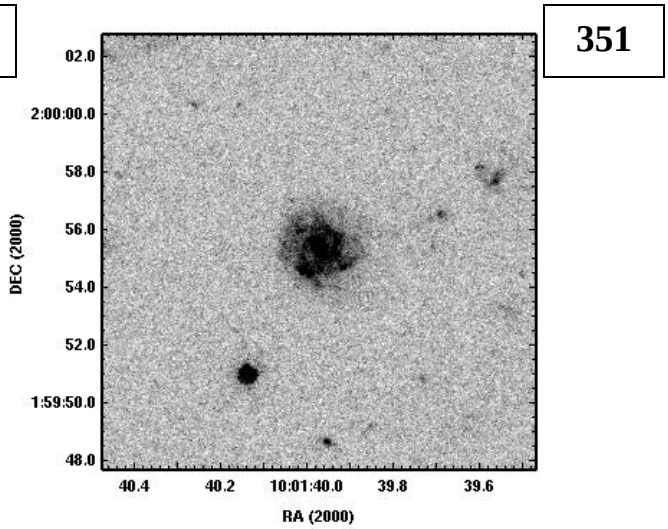
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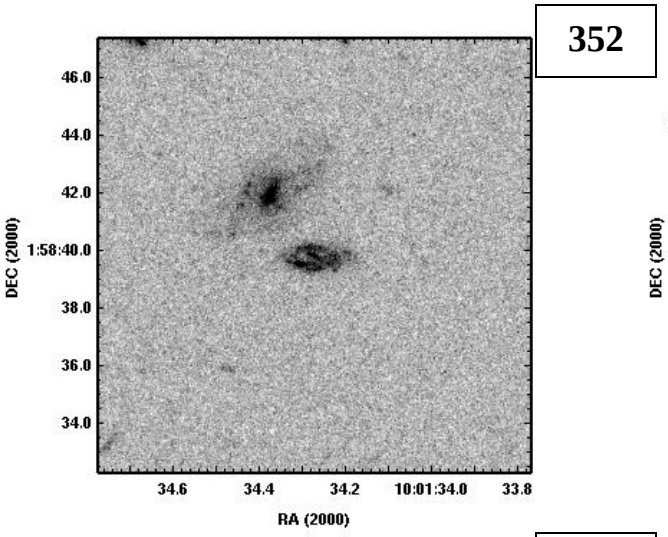
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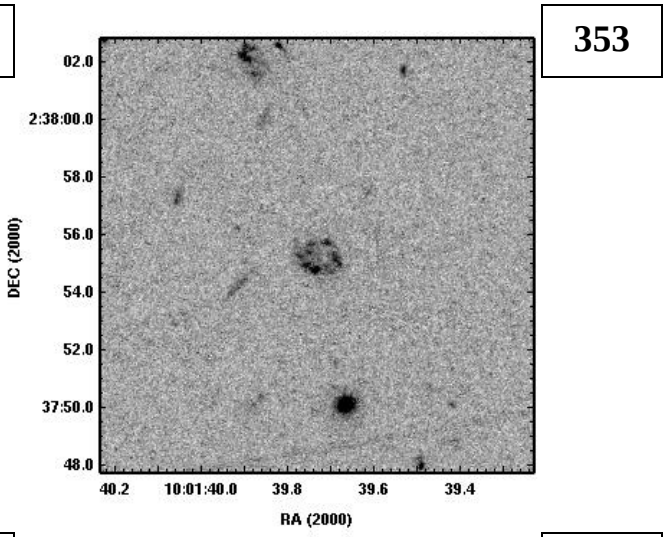
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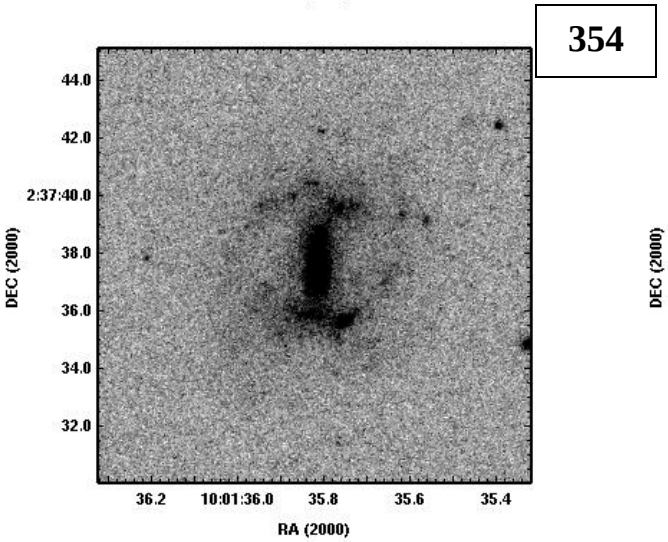
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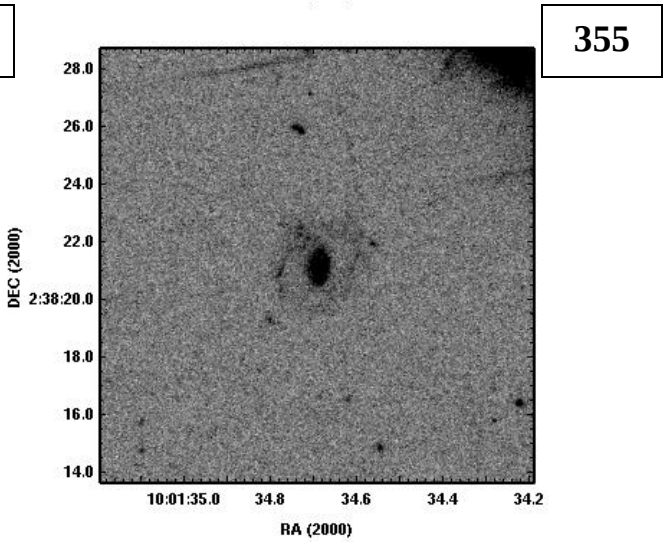
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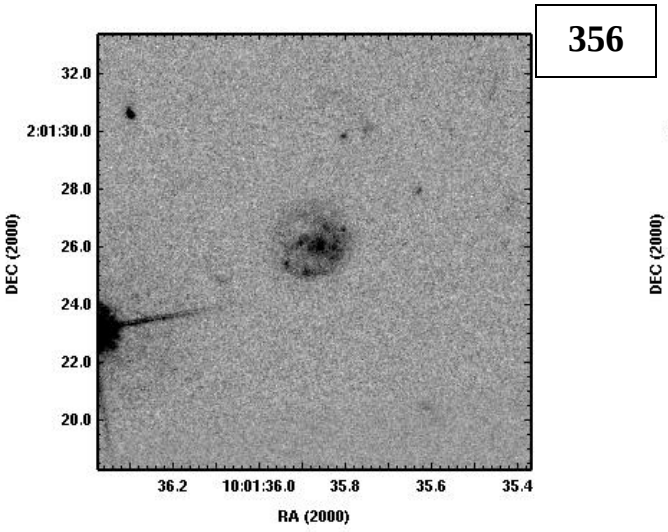
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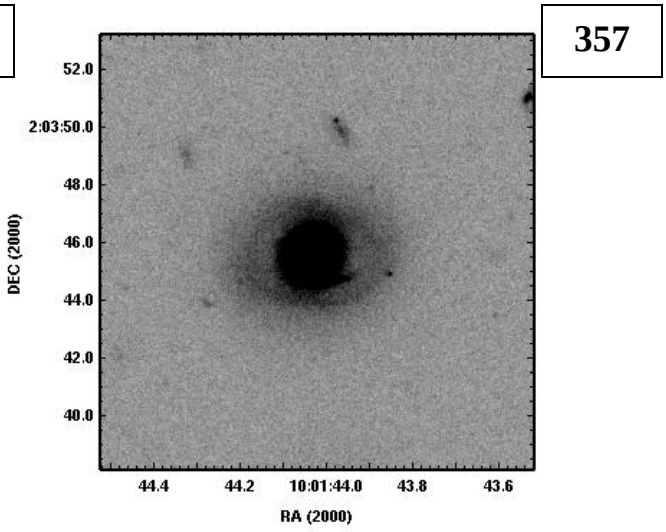
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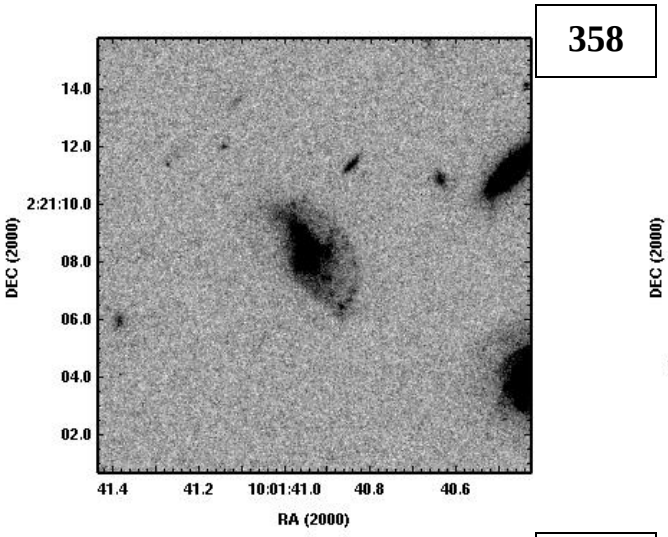
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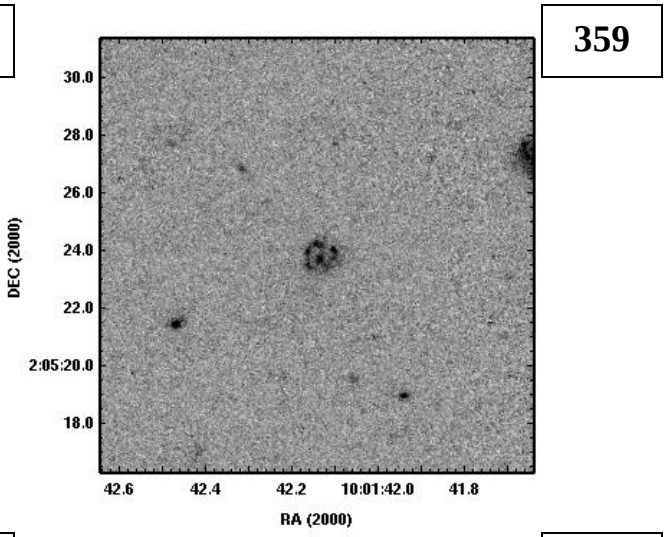
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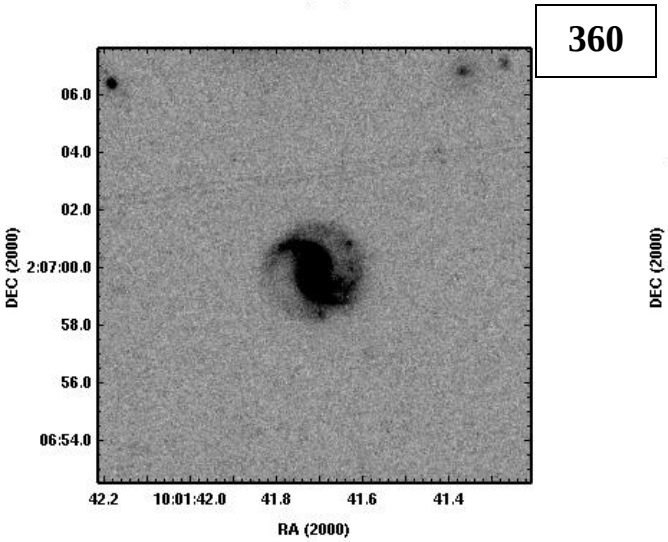
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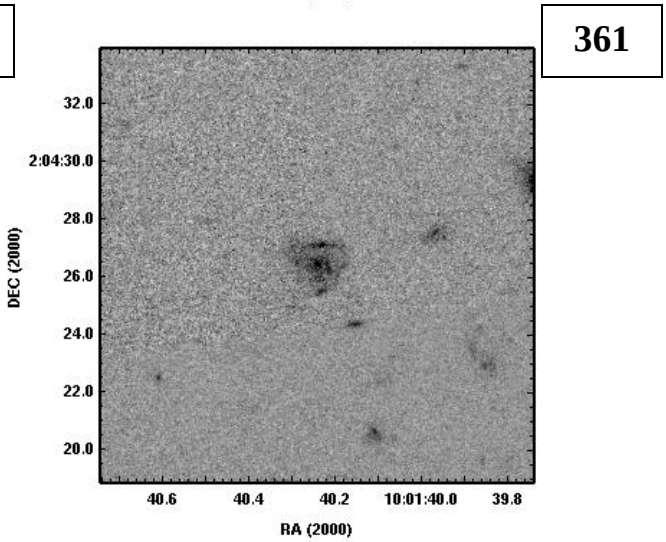
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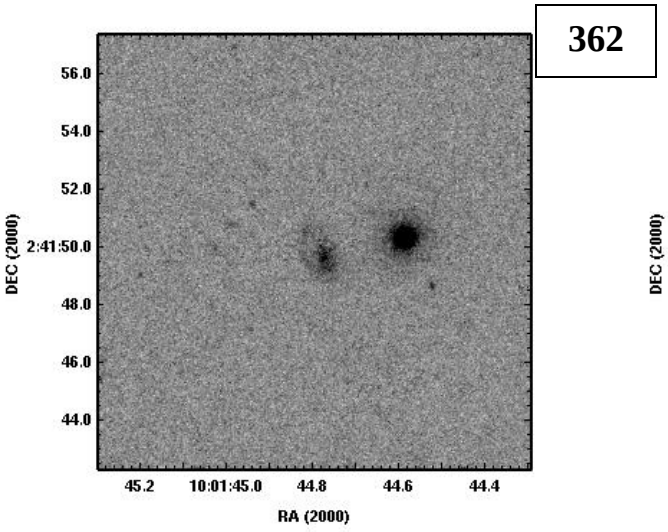
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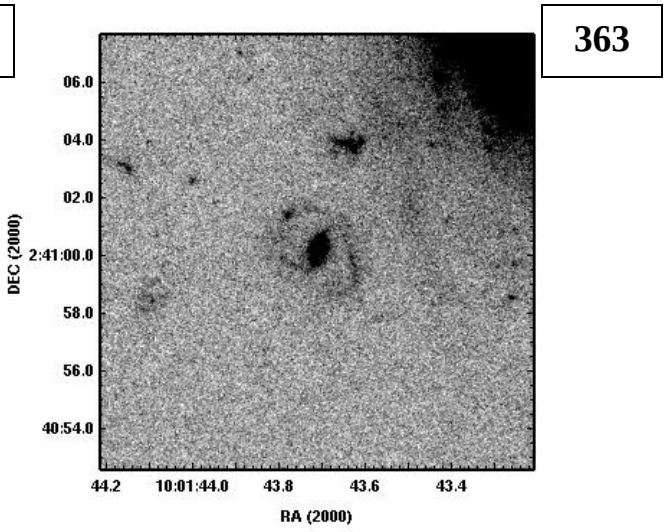
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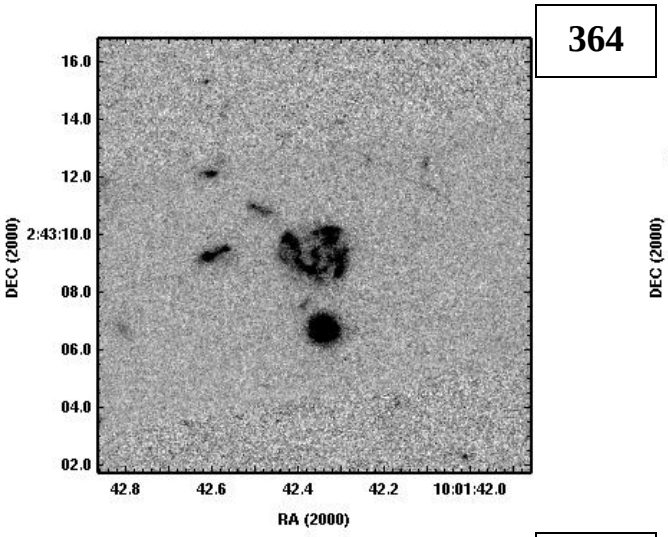
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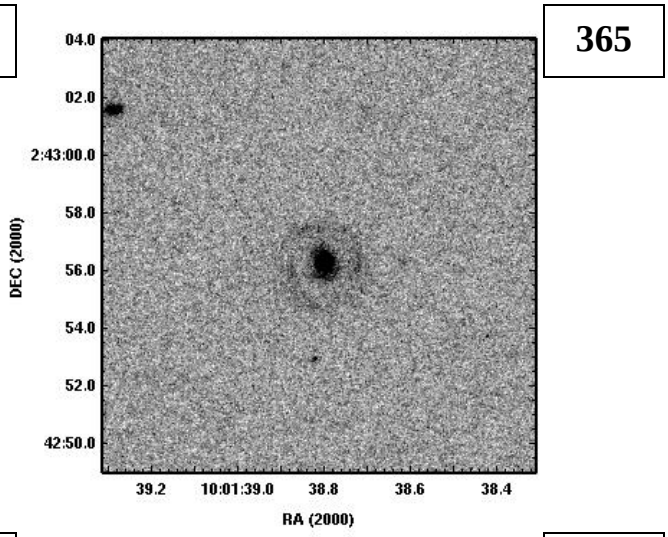
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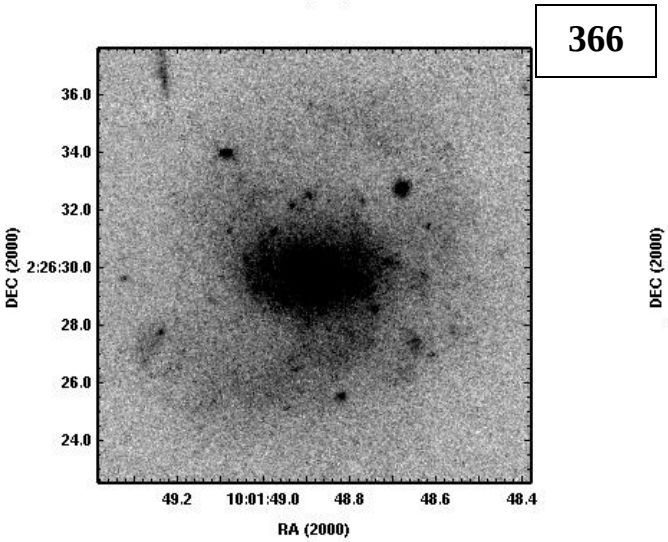
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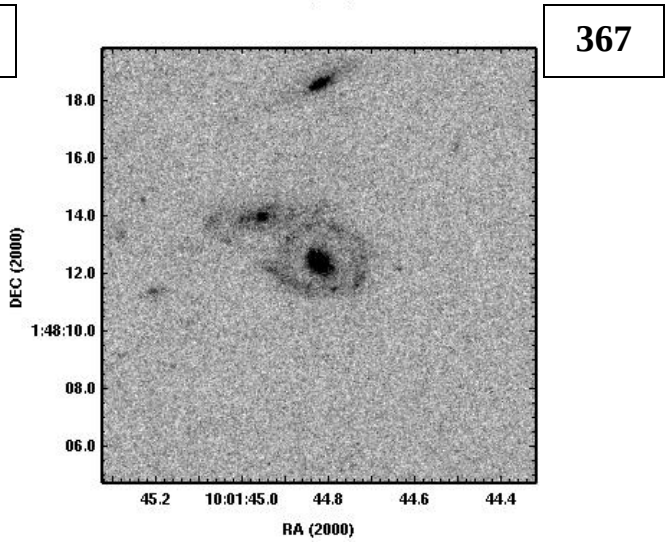
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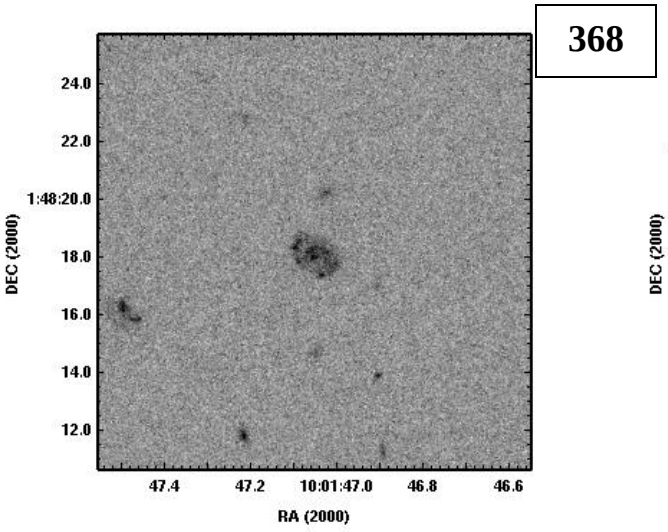
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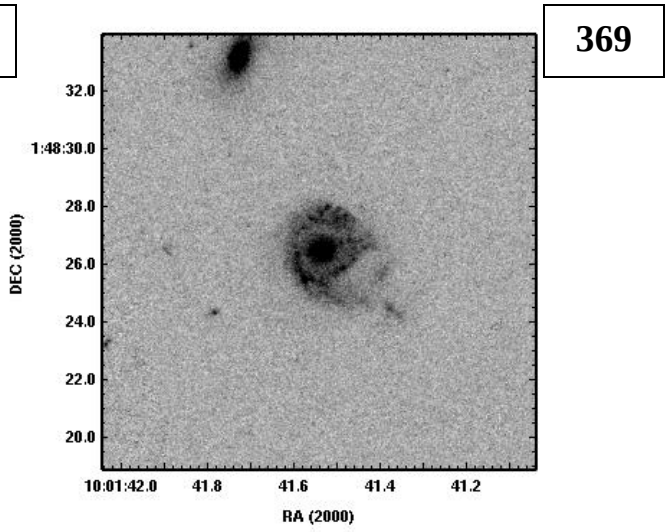
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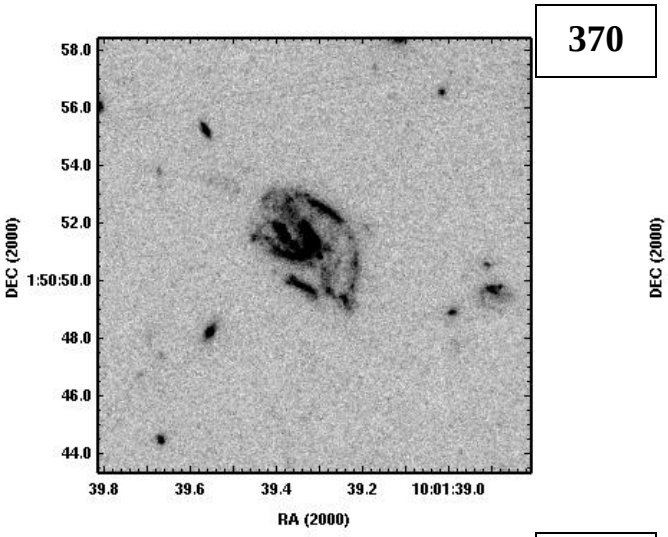
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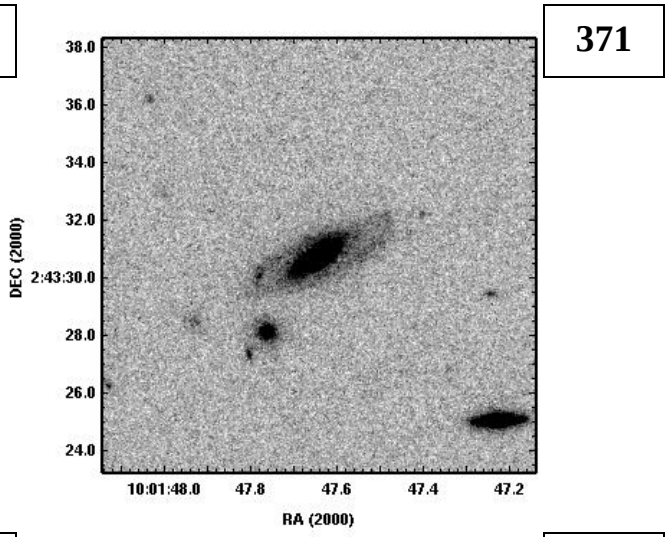
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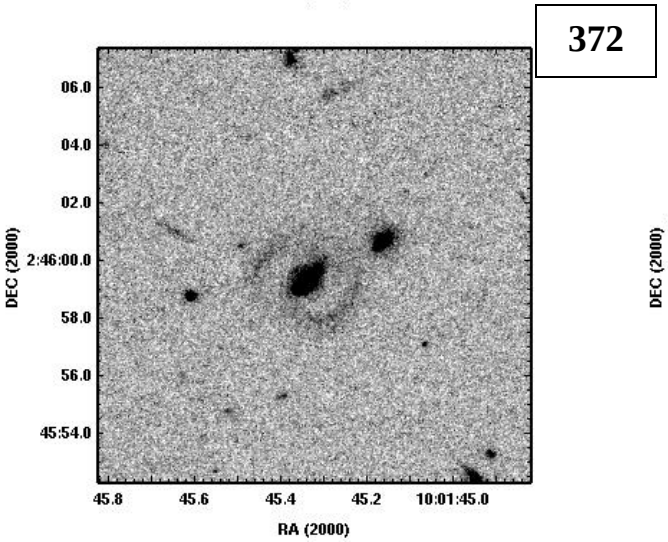
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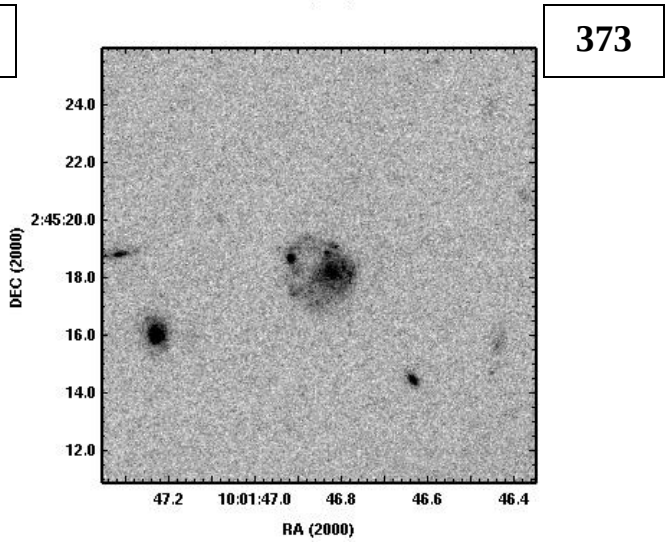
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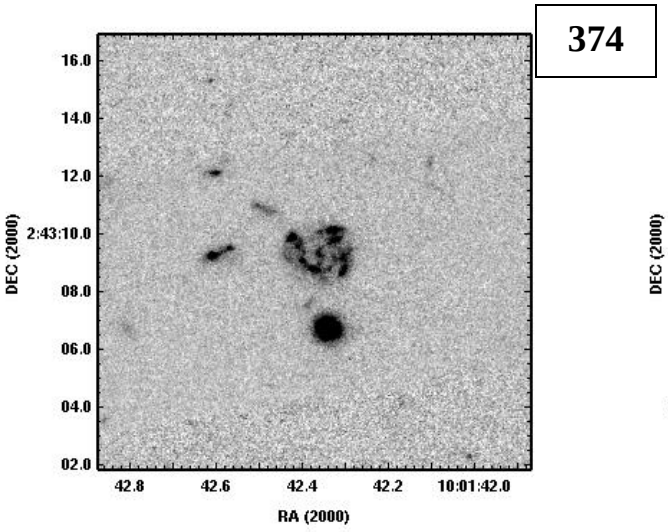
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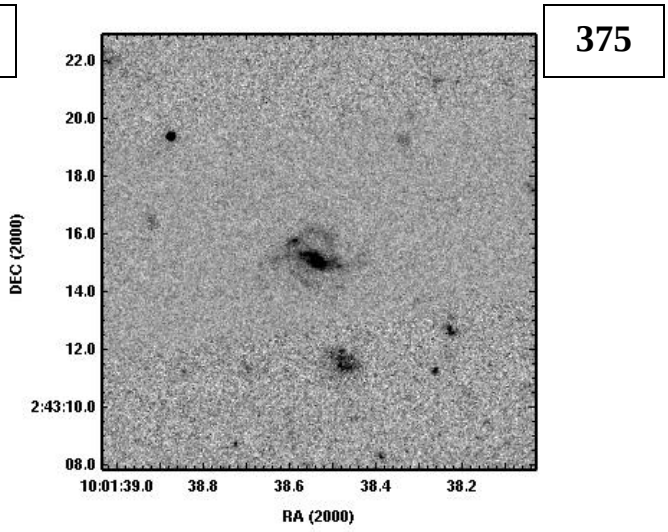
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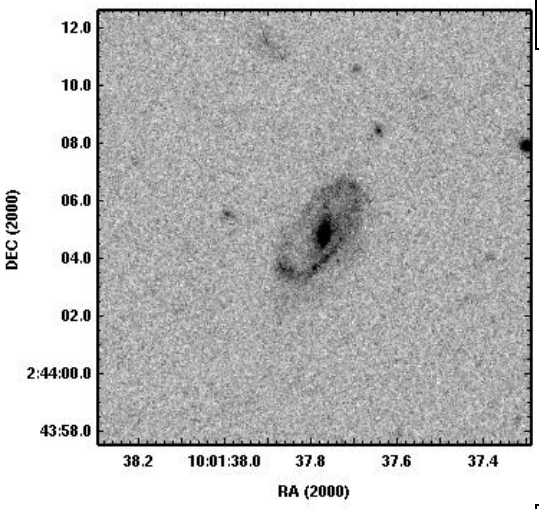
376



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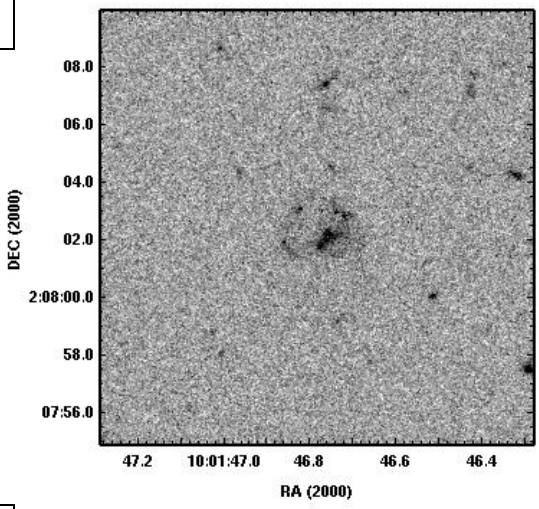

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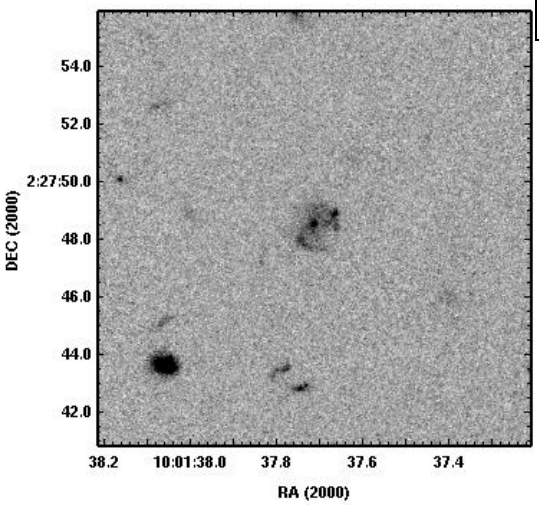

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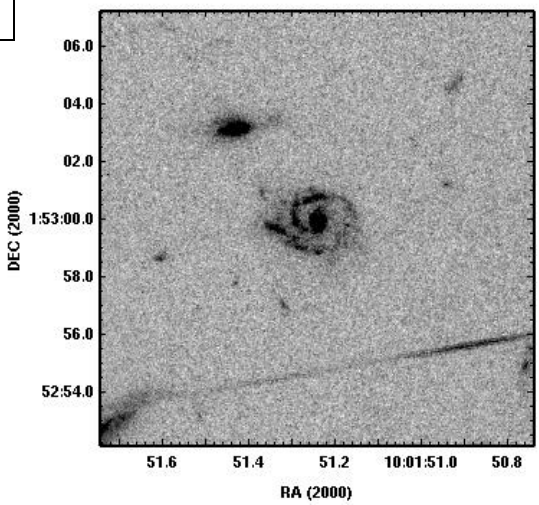

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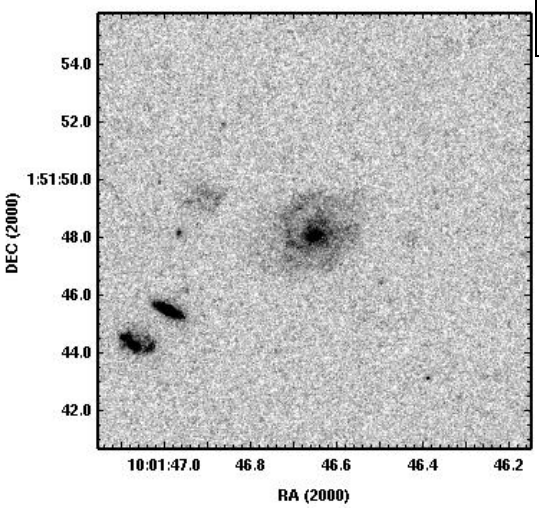

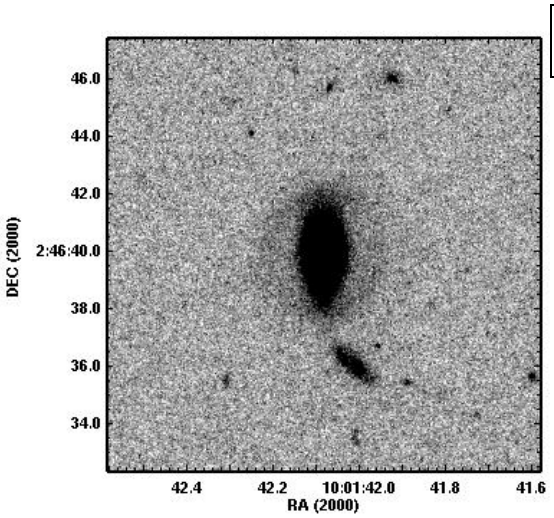
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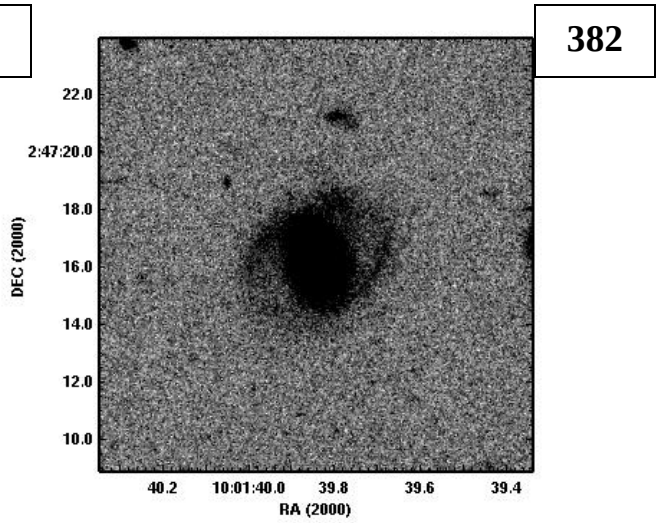
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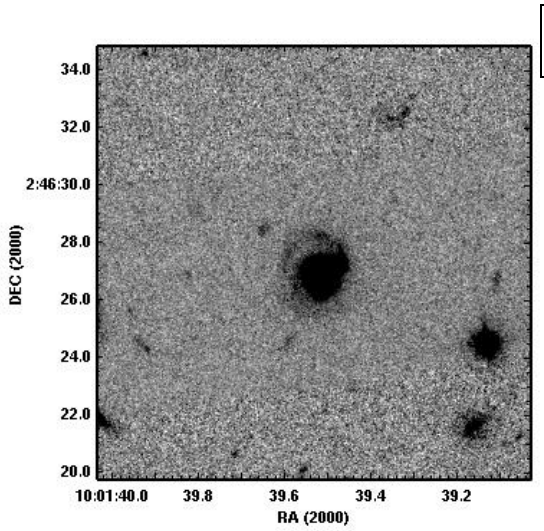
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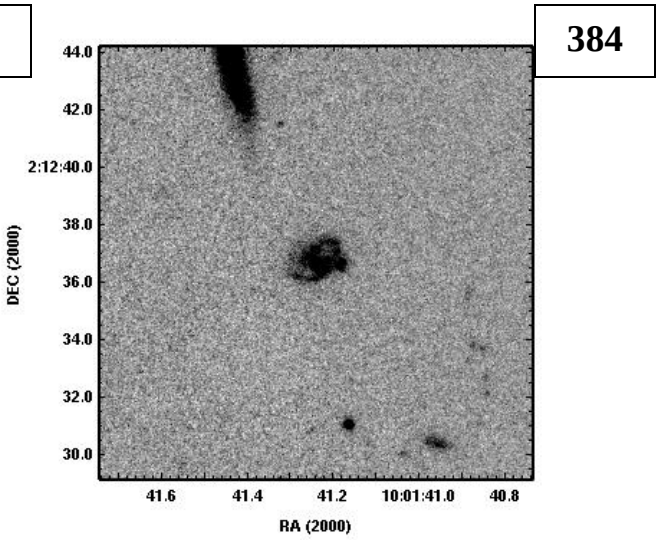
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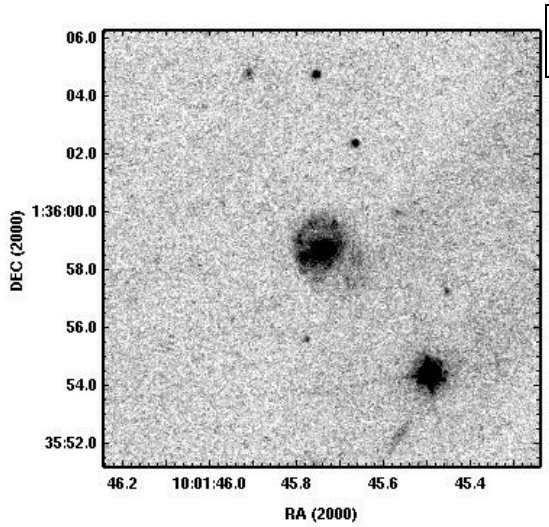
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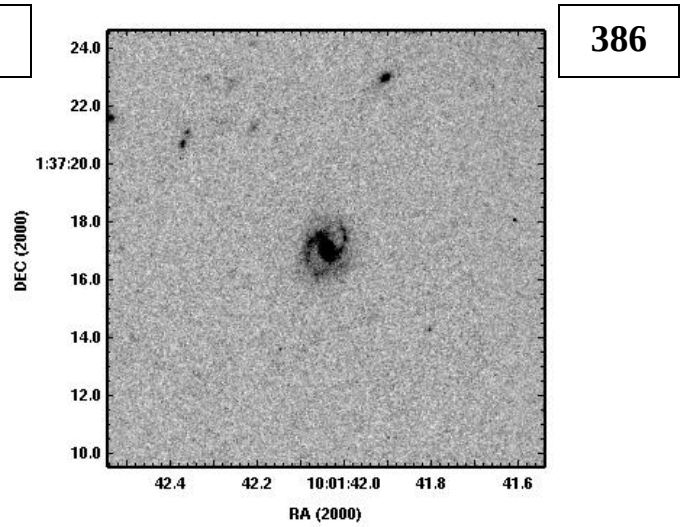
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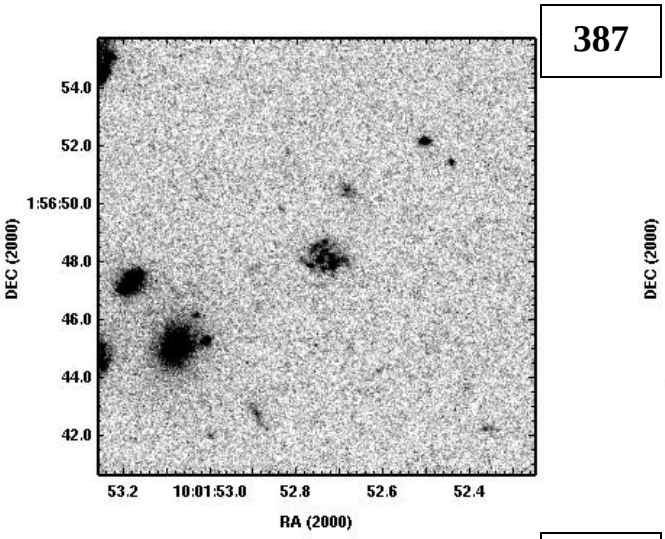
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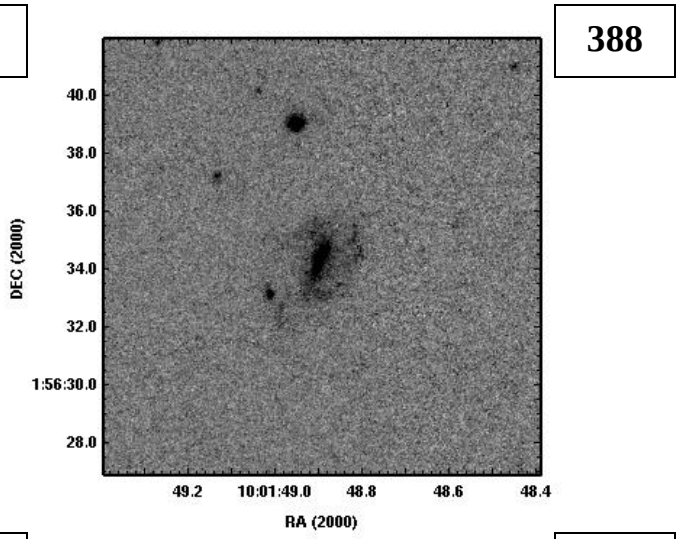
388
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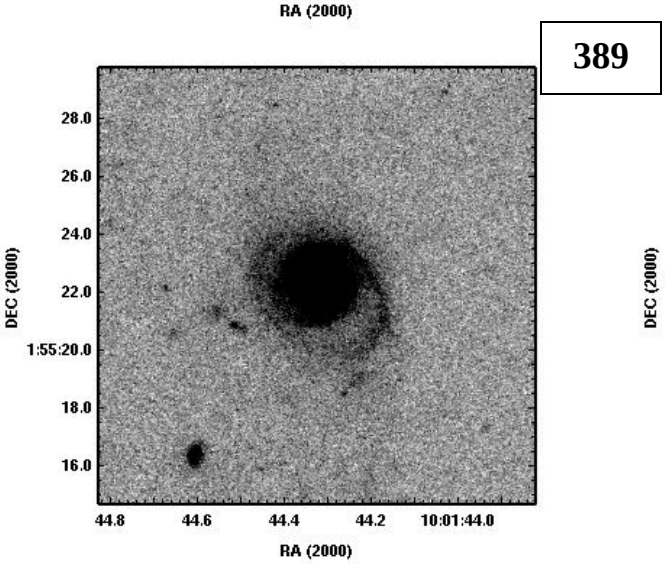
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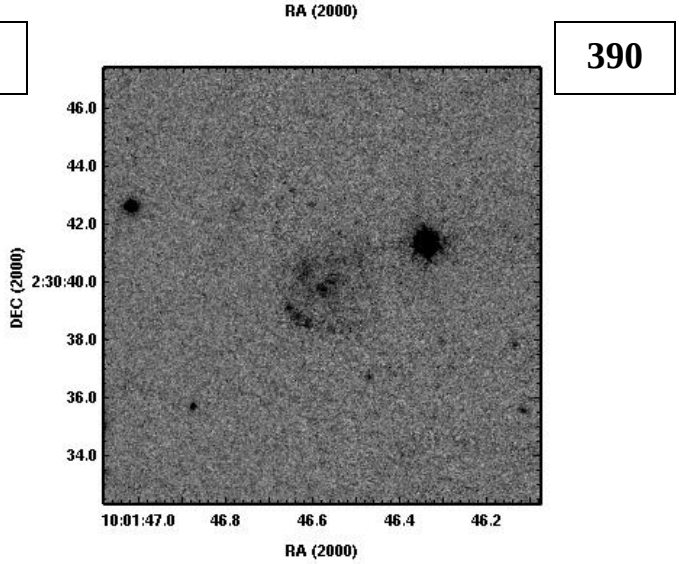
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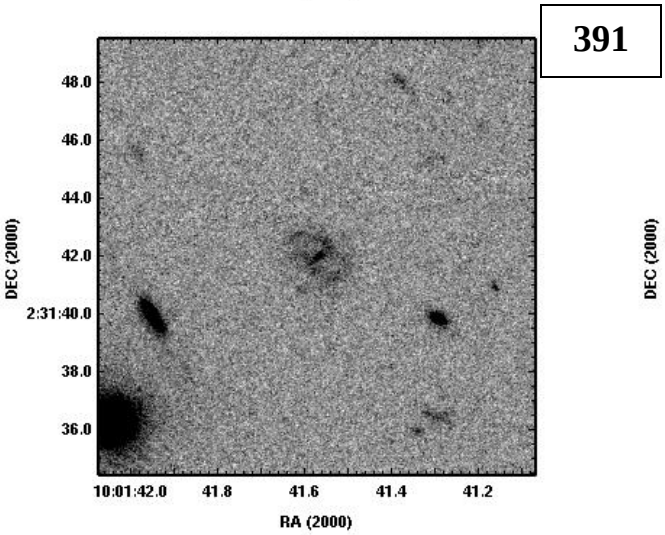
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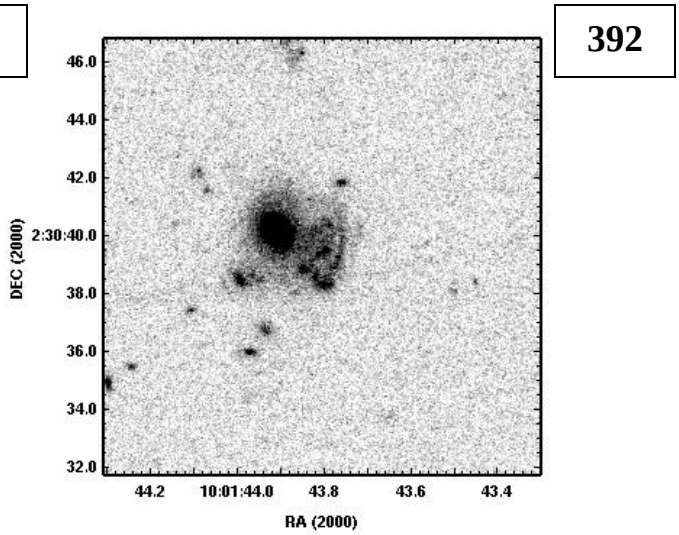
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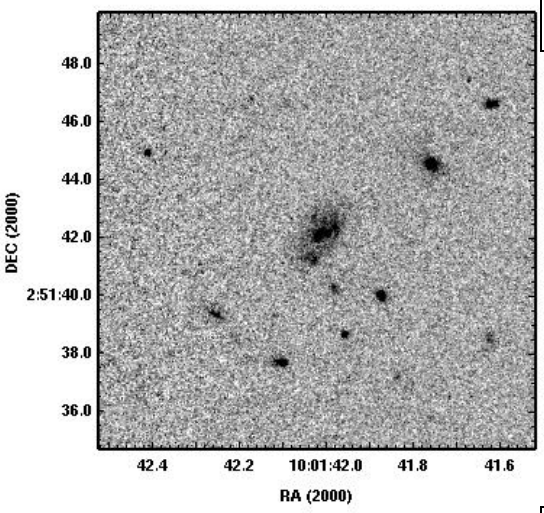

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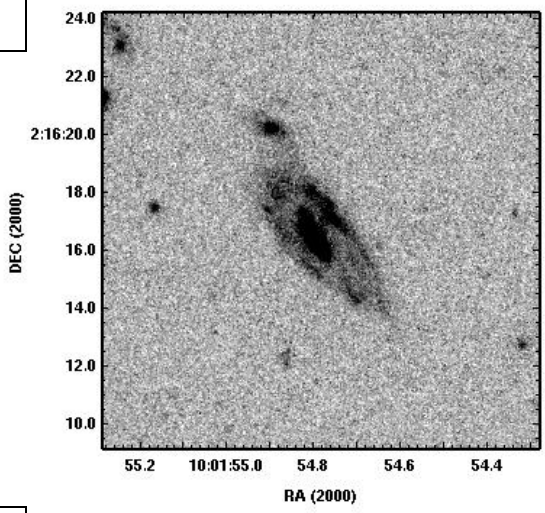

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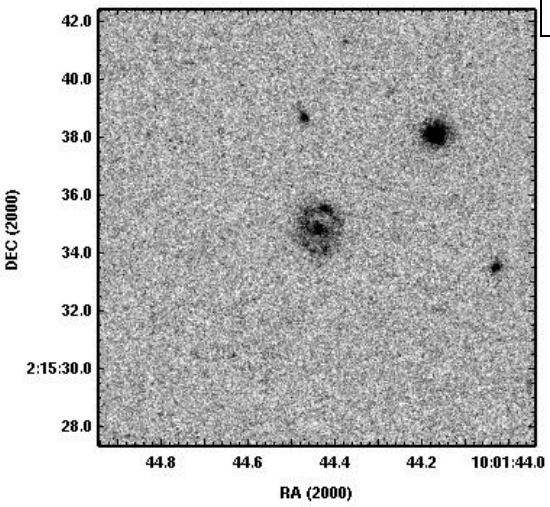

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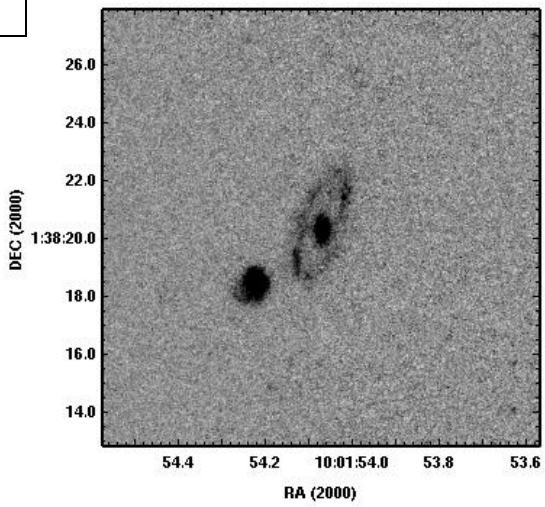

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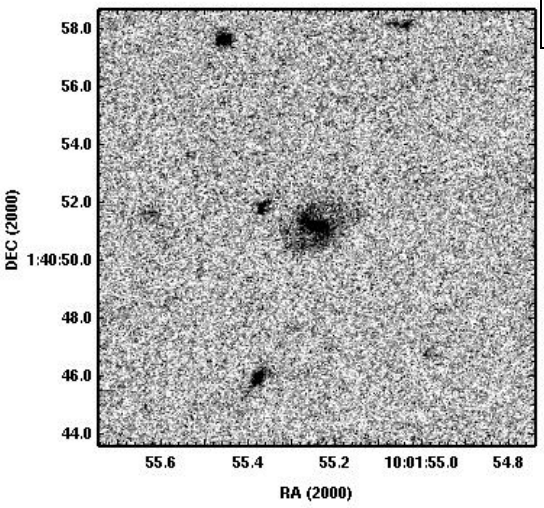

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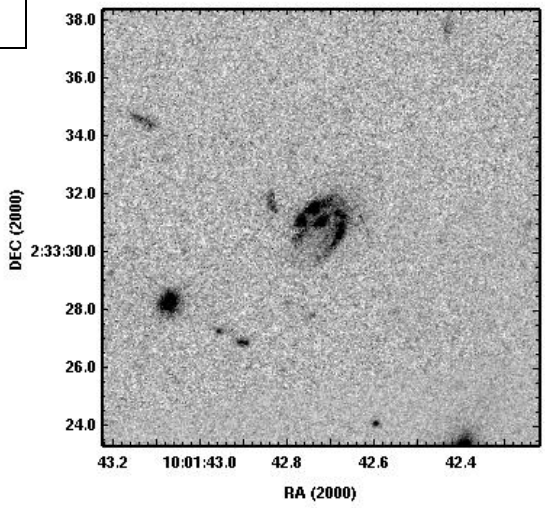

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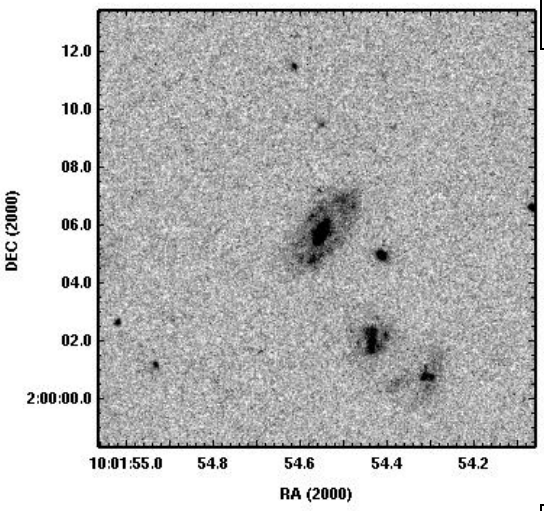

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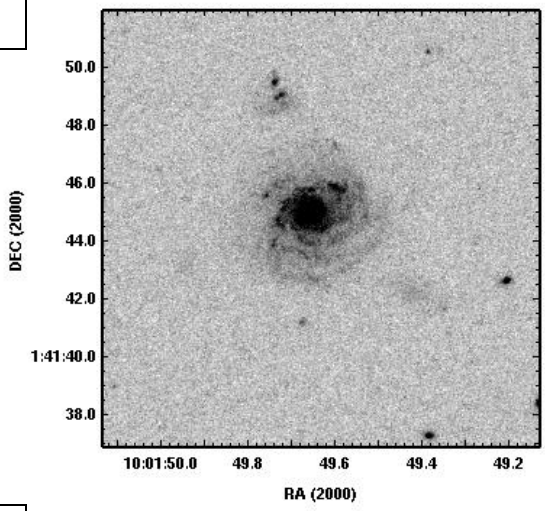

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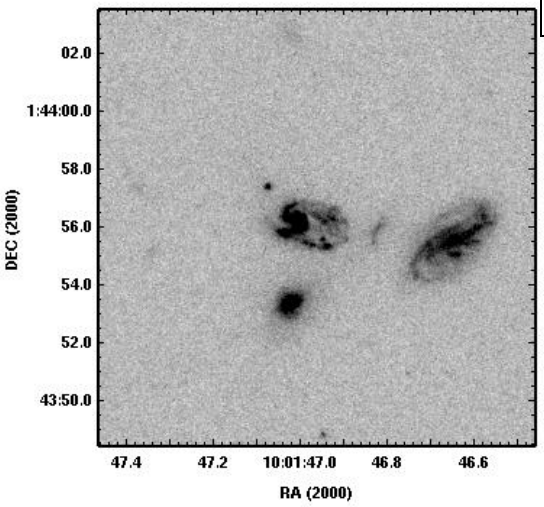

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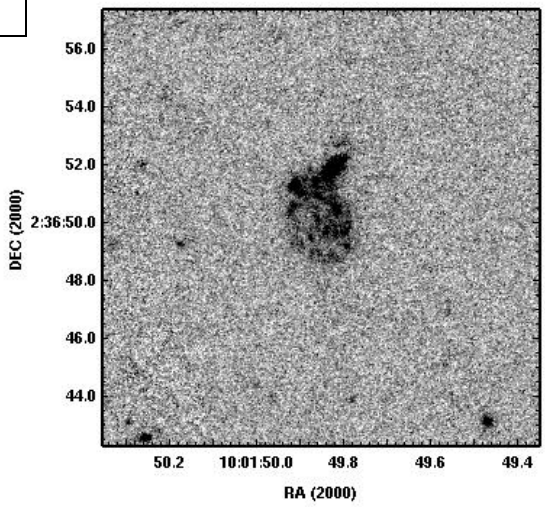

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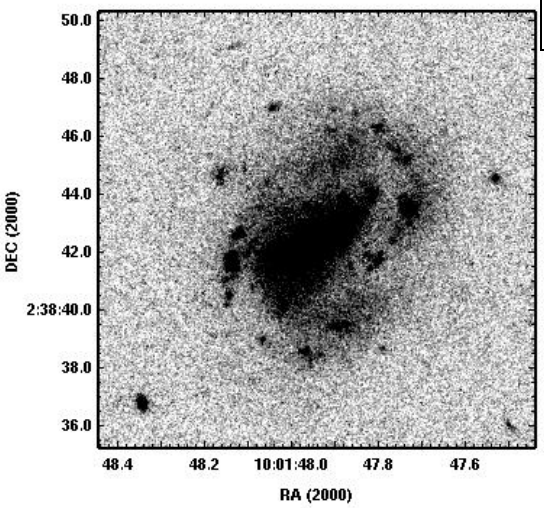

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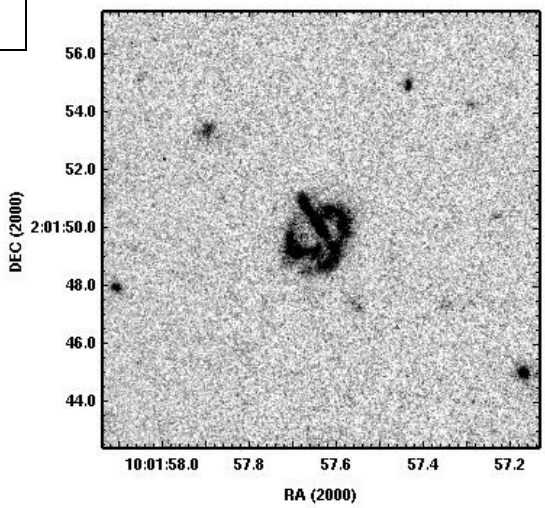

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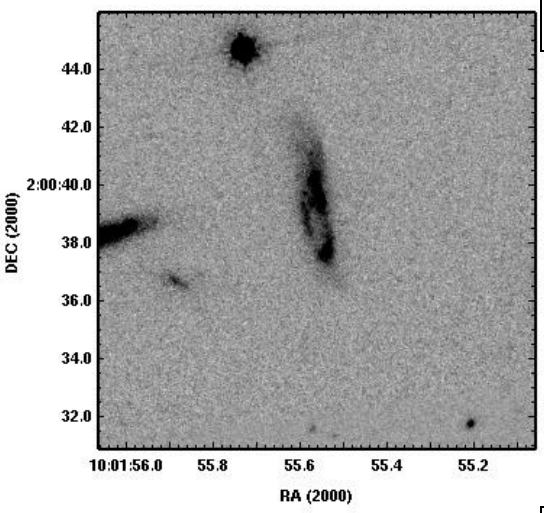

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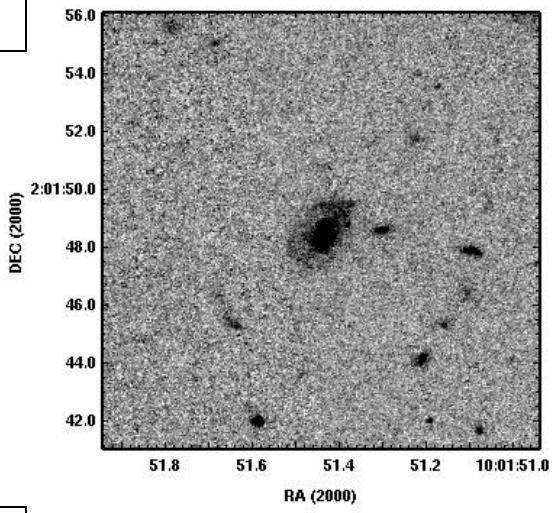

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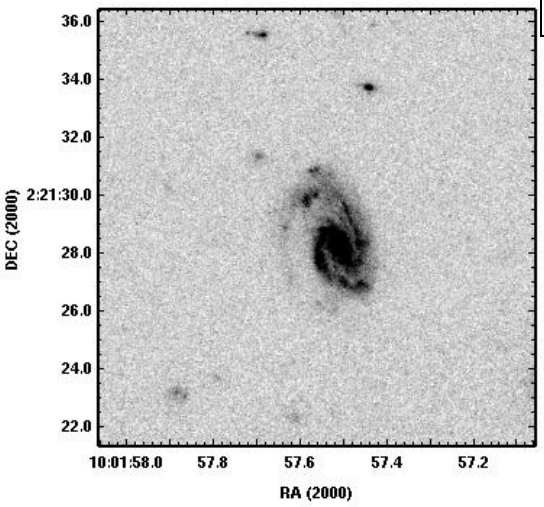

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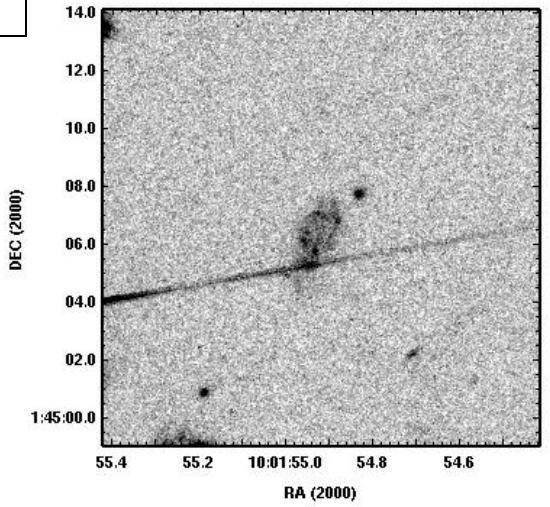

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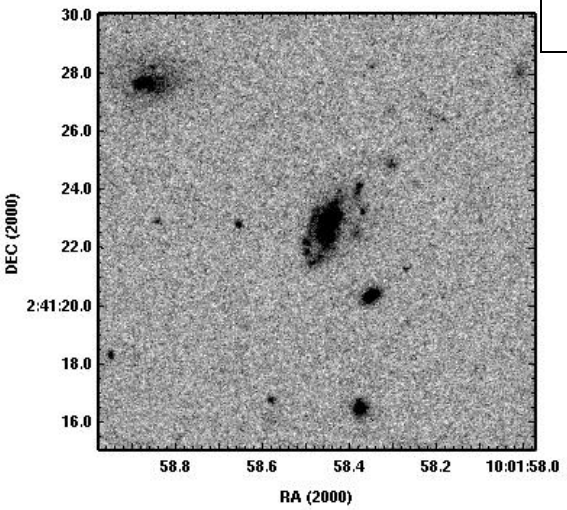

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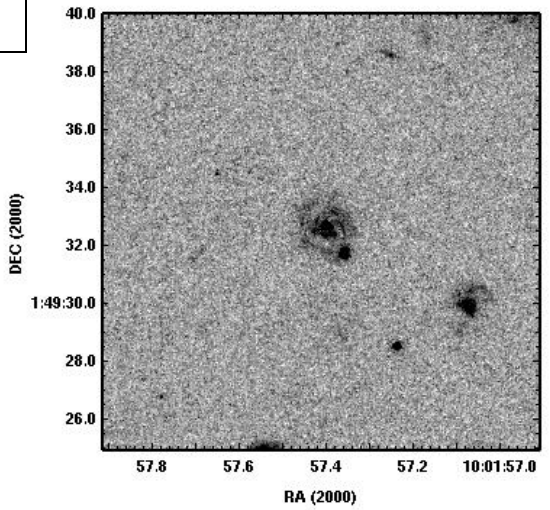

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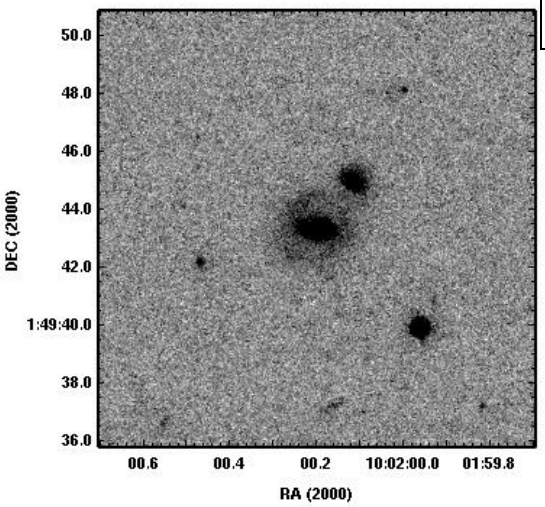

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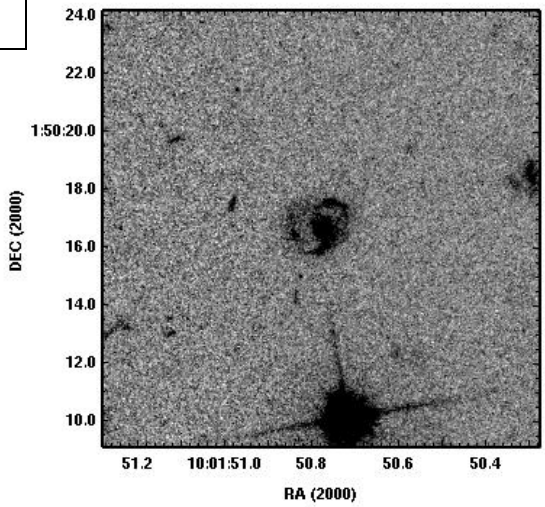

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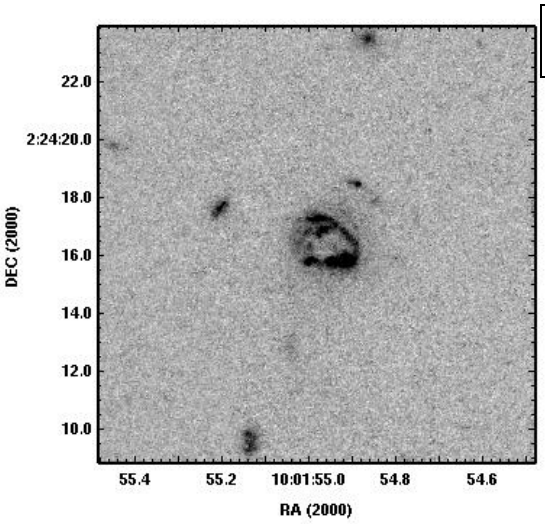

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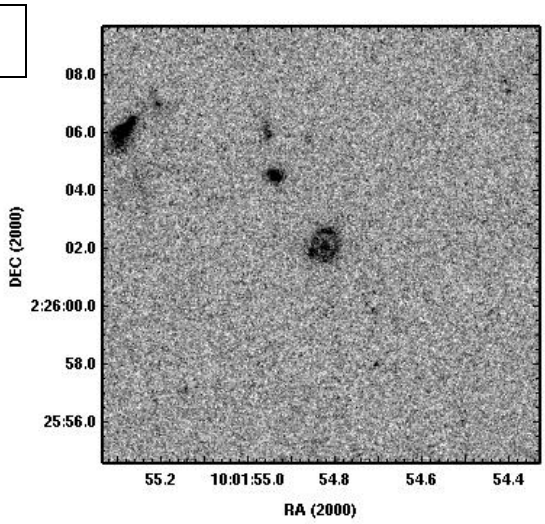

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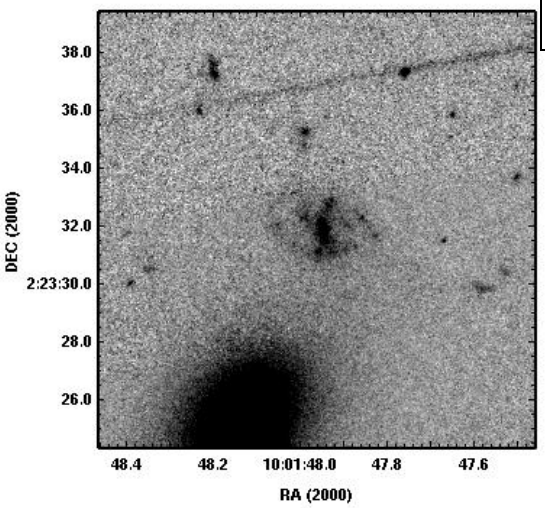

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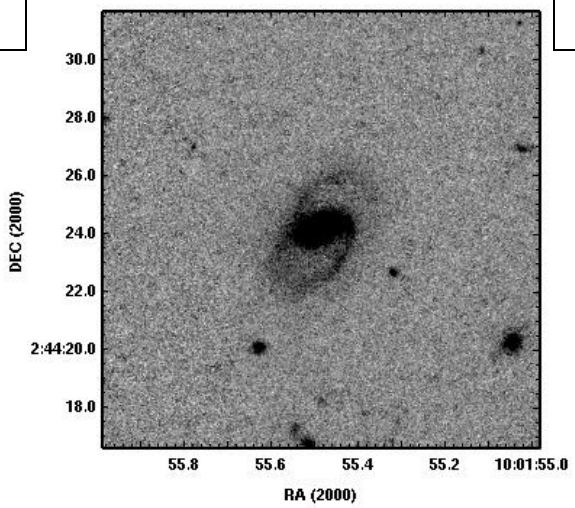

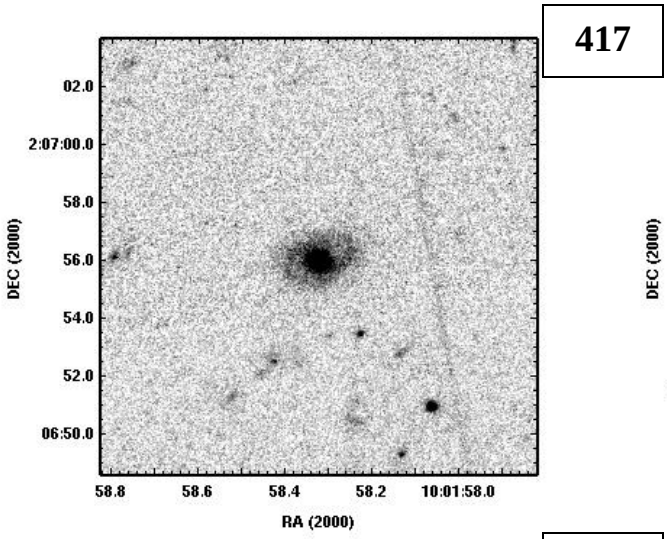
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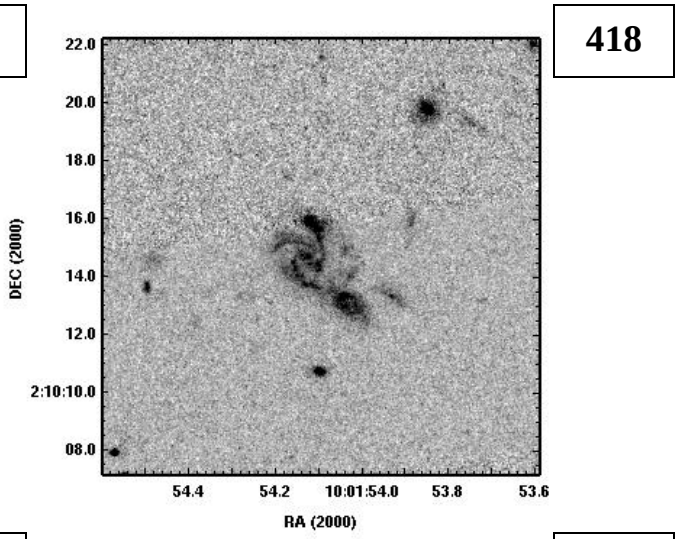
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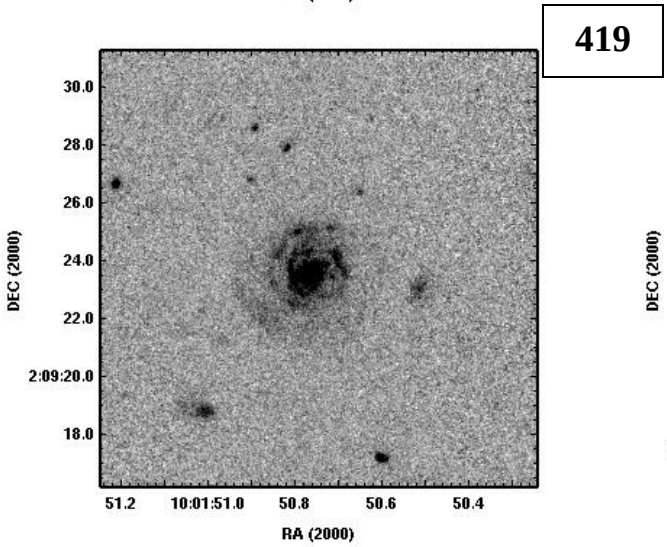
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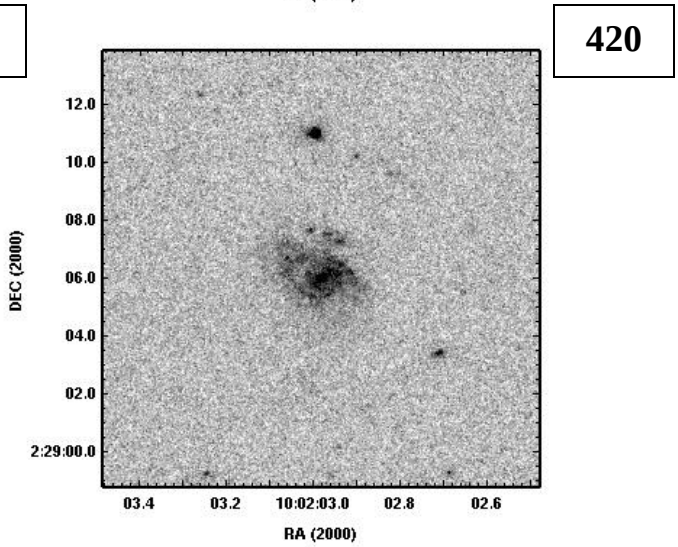
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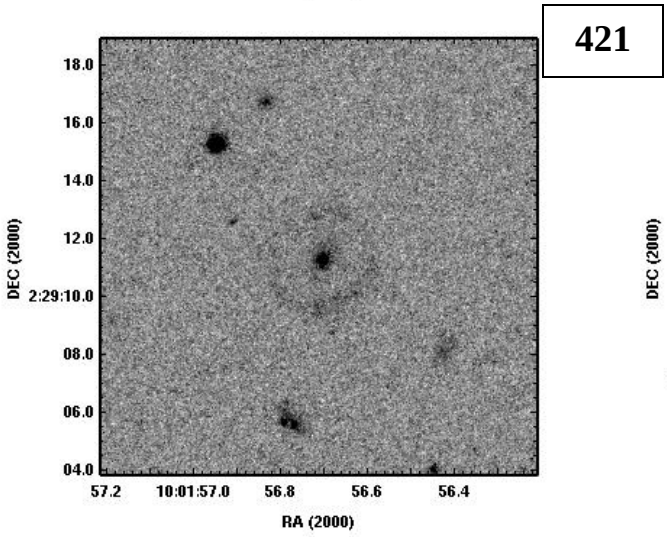
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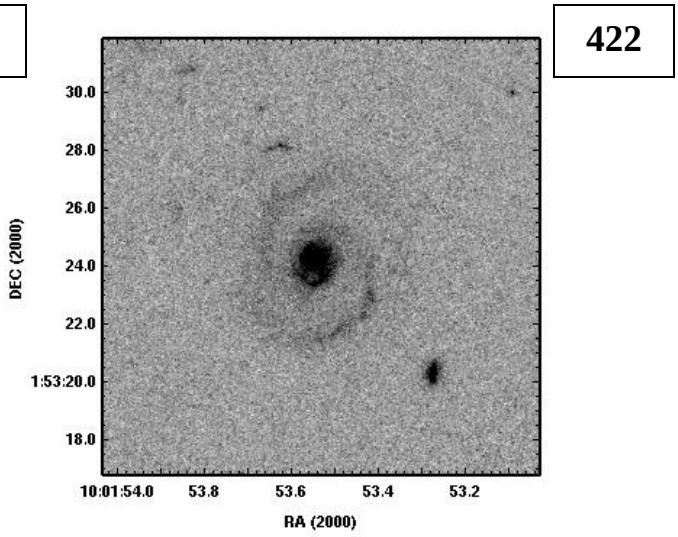
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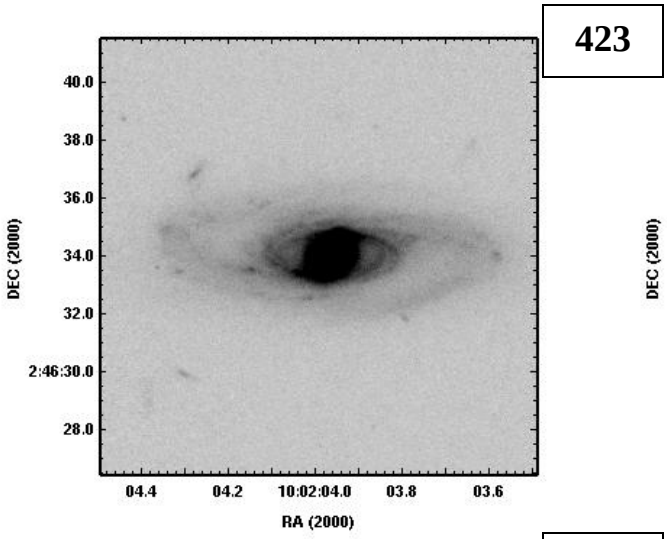
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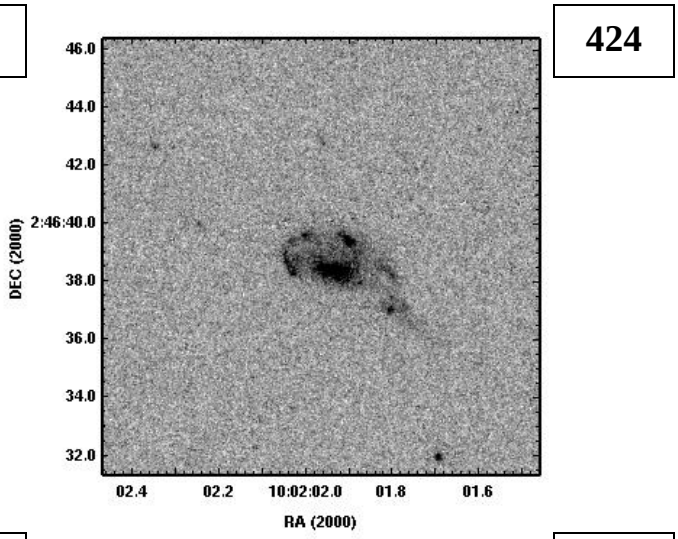
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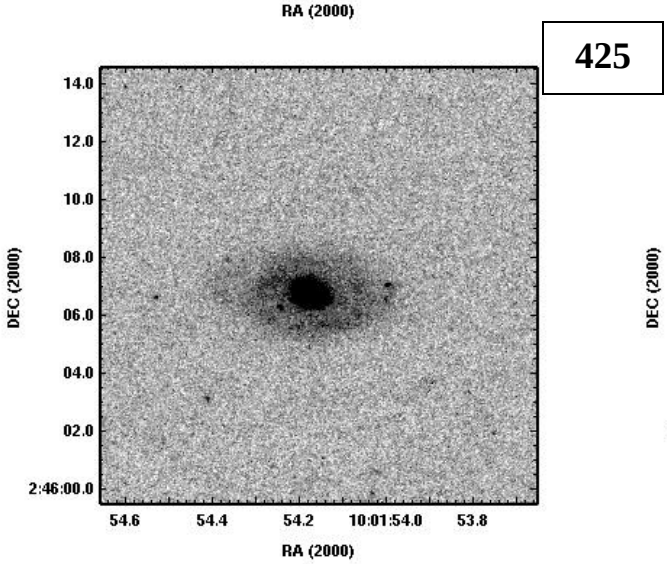
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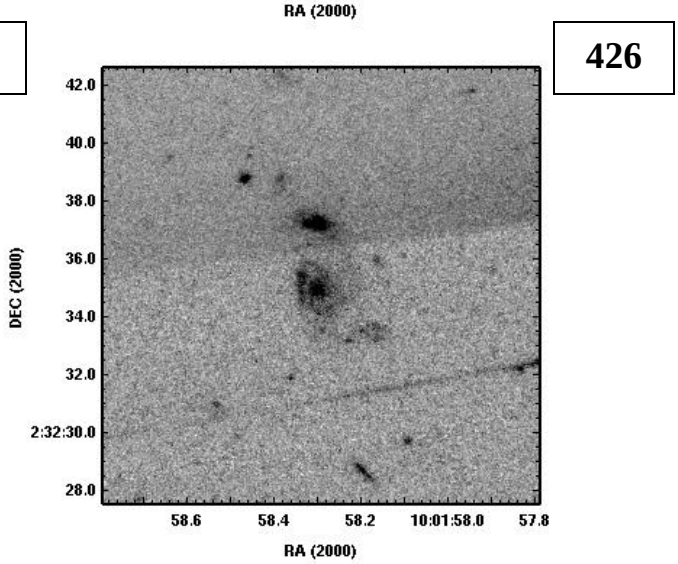
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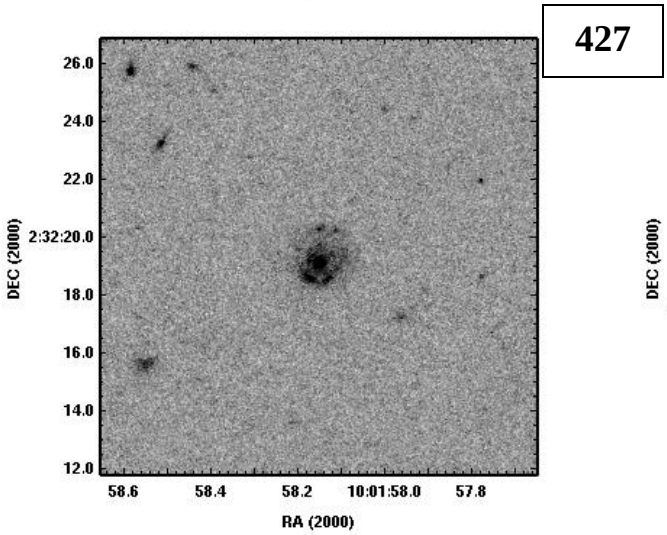
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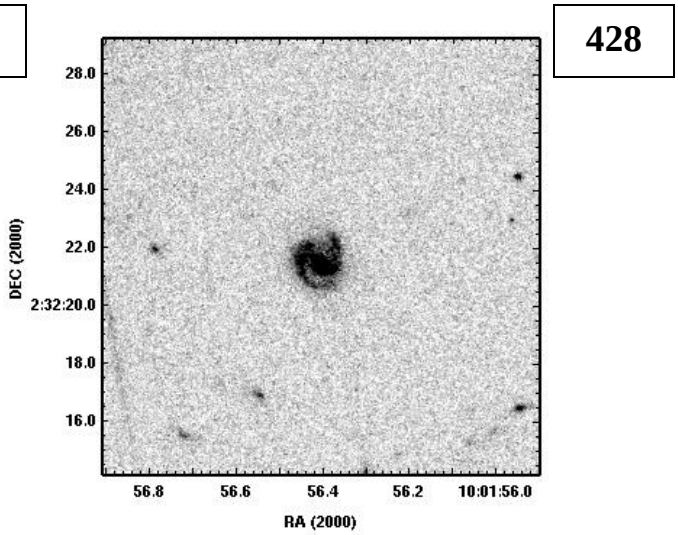
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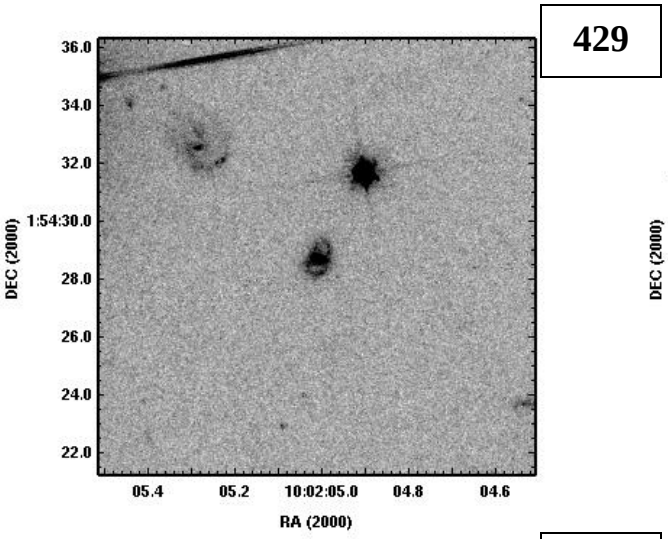
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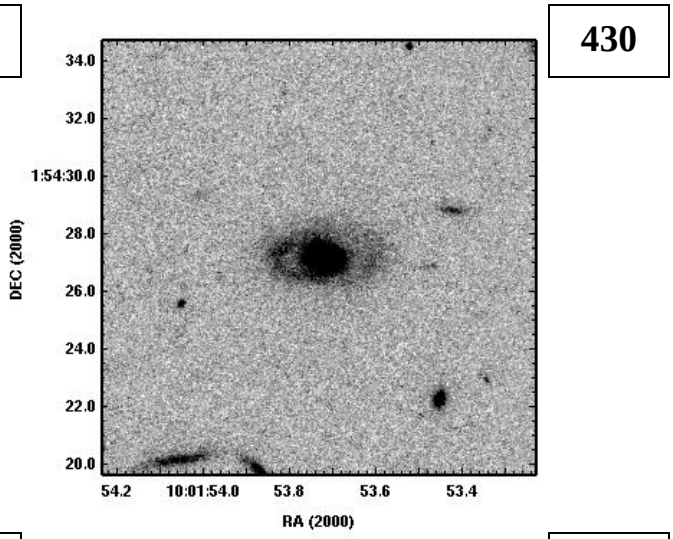
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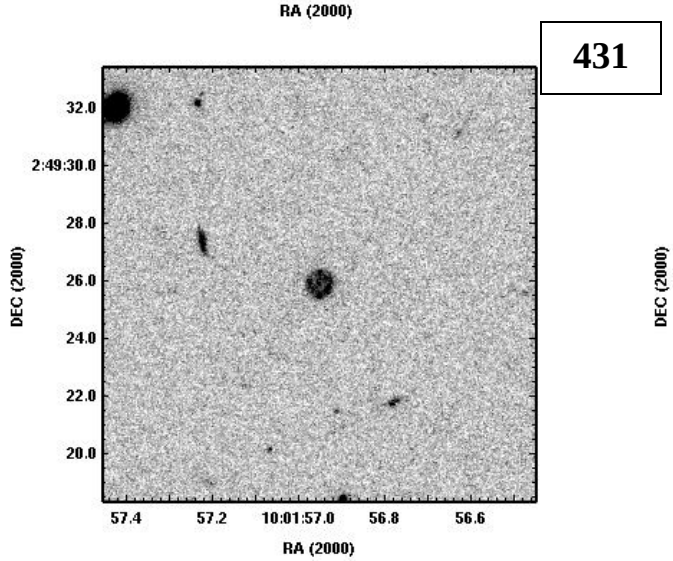
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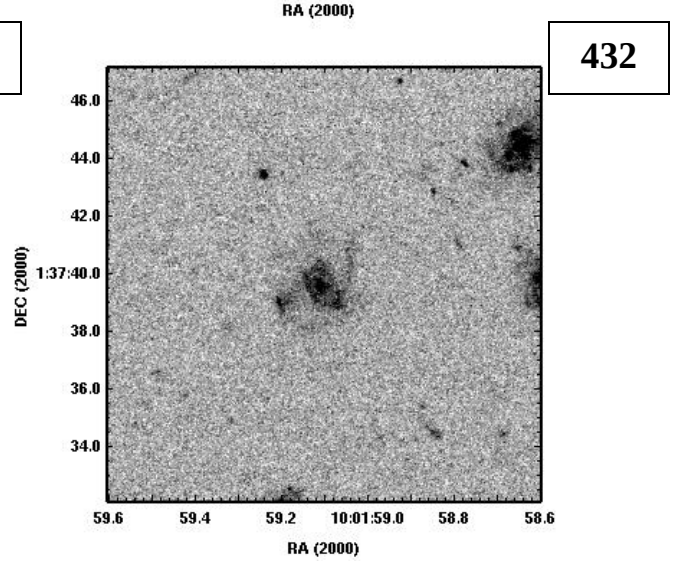
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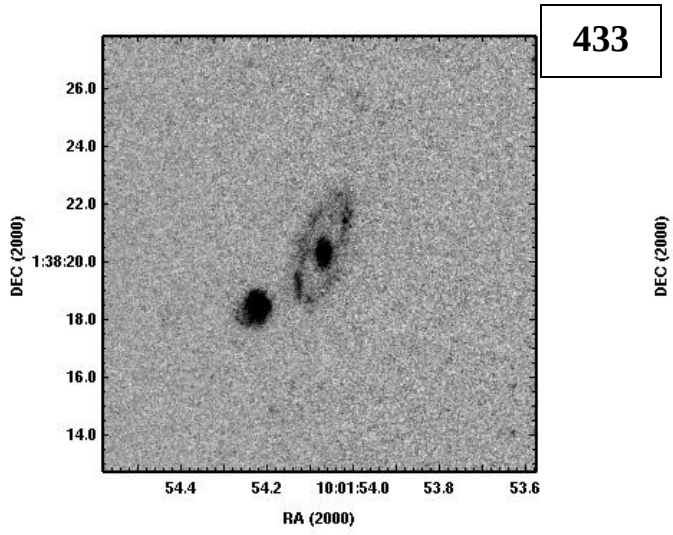
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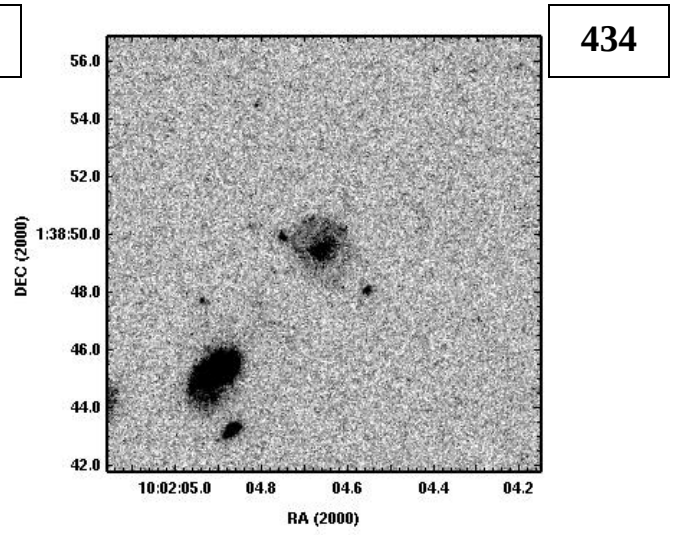
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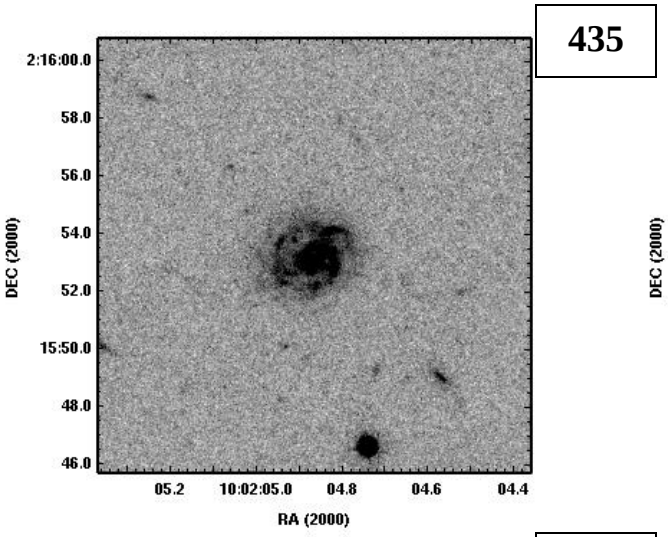
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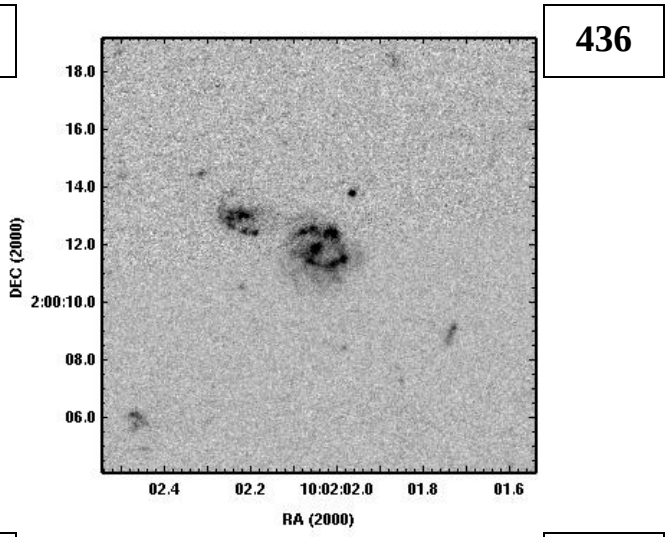
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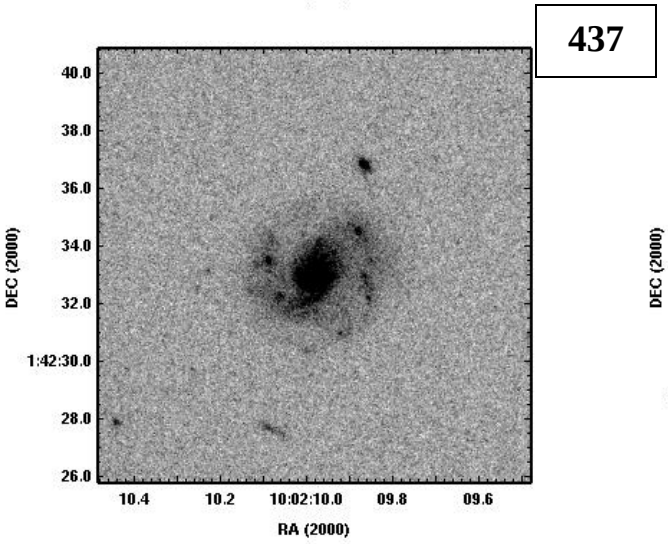
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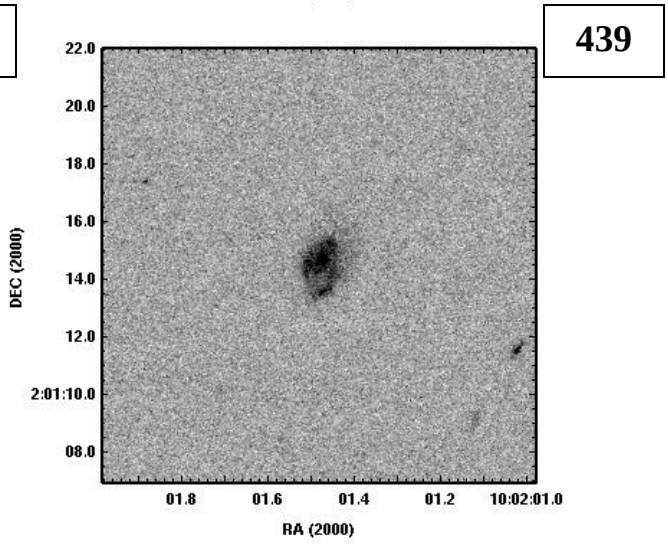
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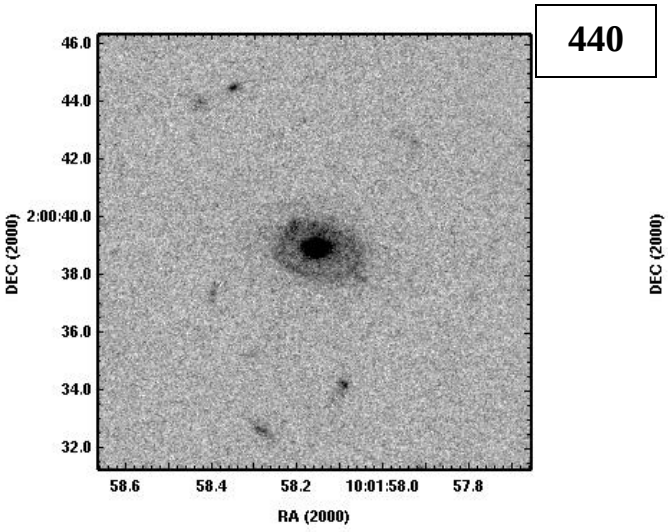
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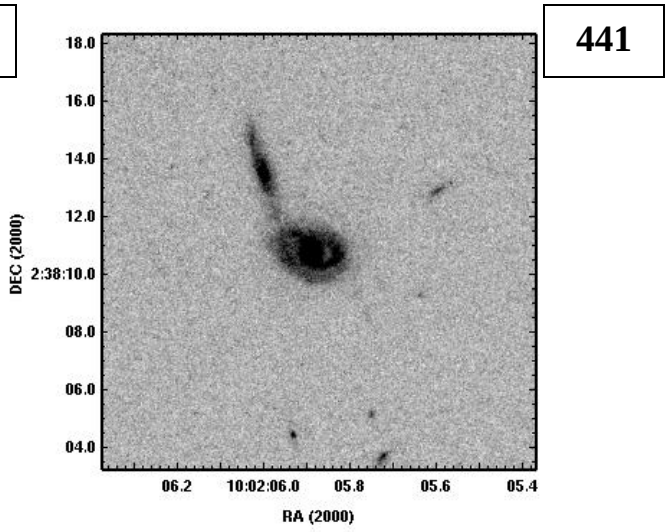
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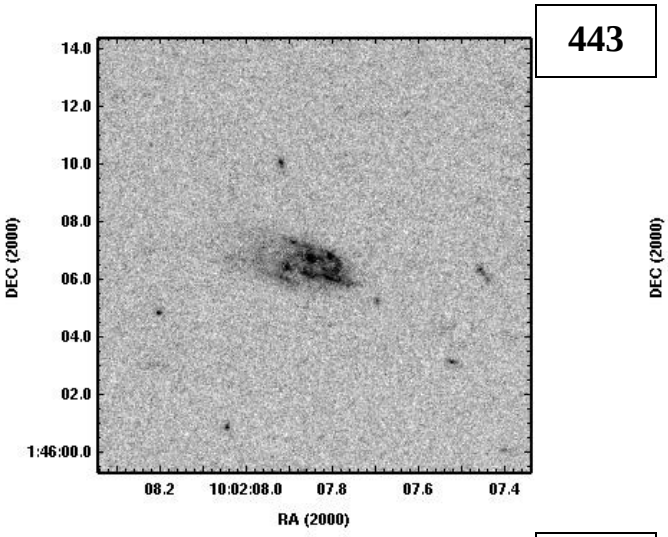
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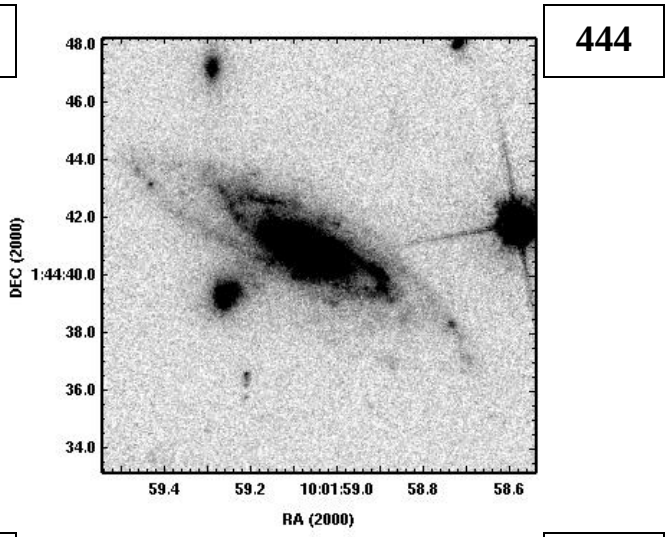
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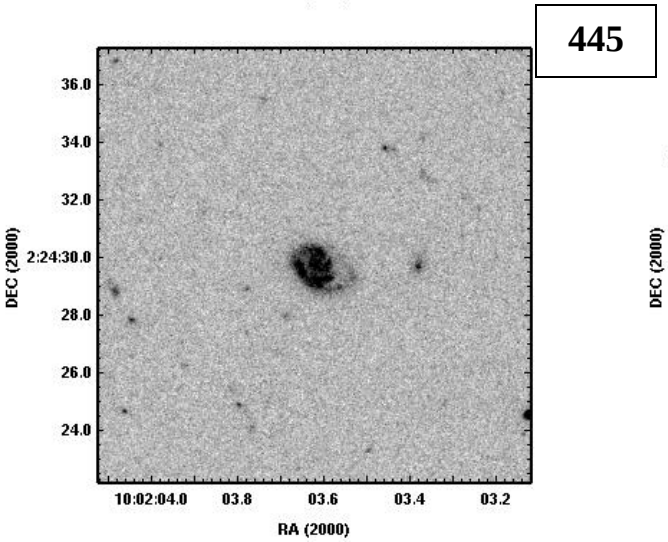
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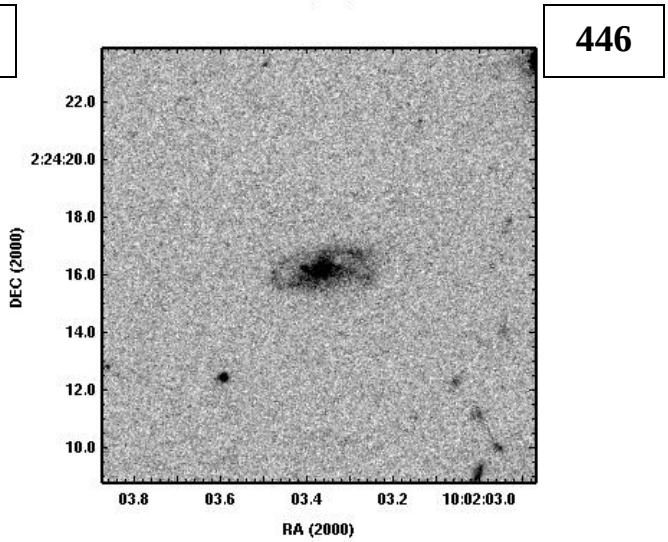
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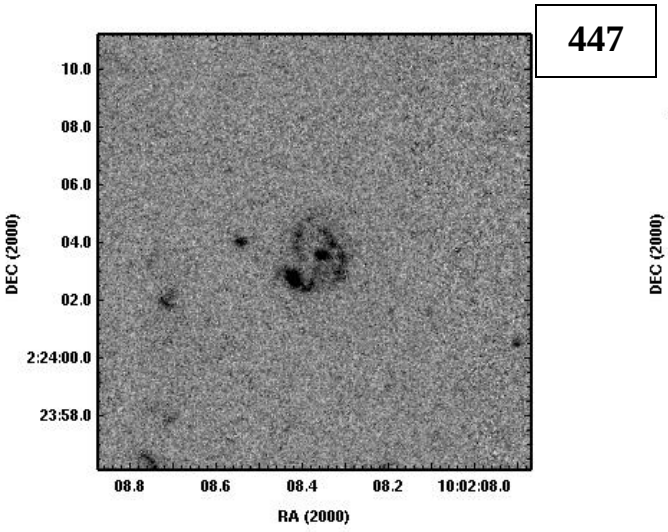
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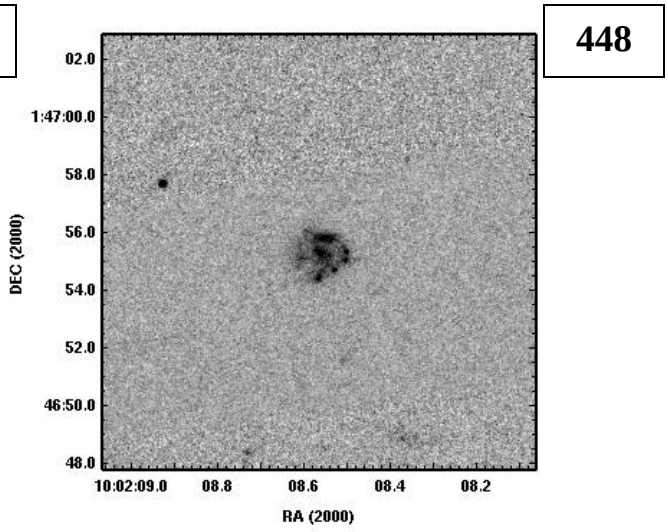
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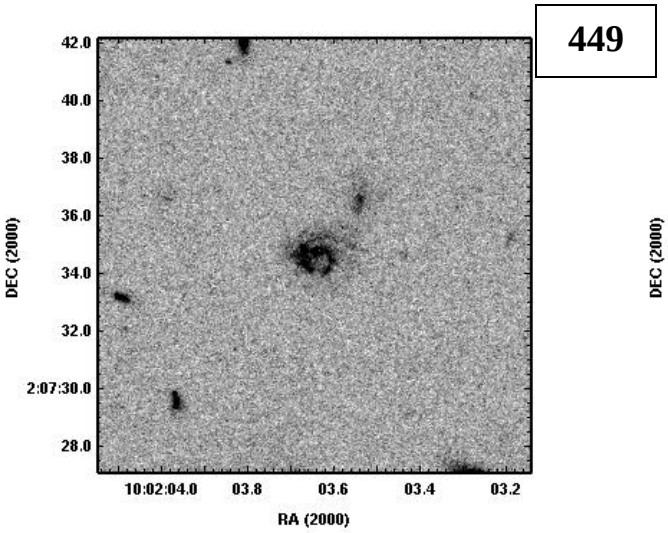
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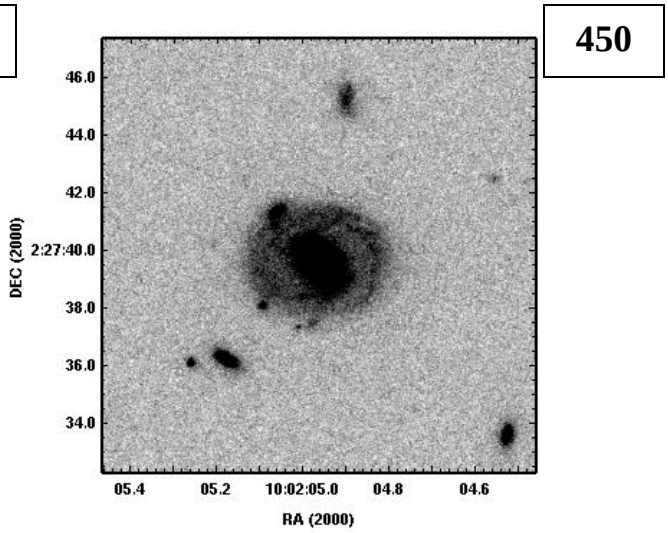
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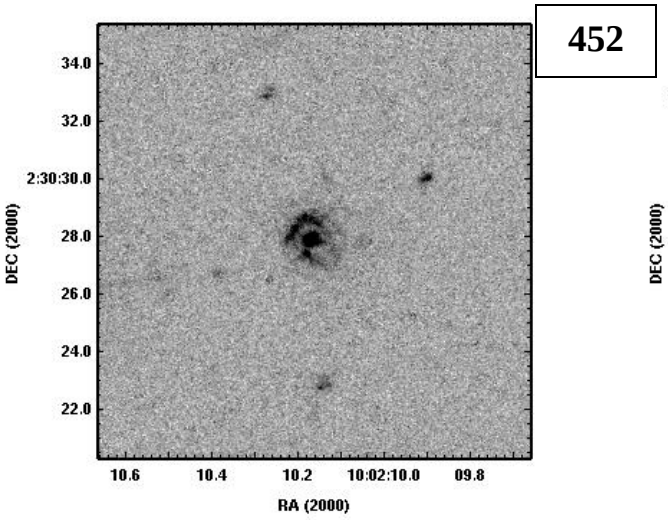
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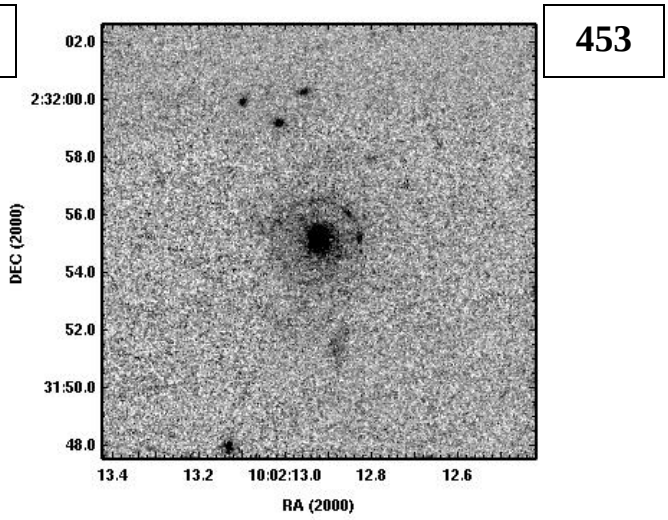
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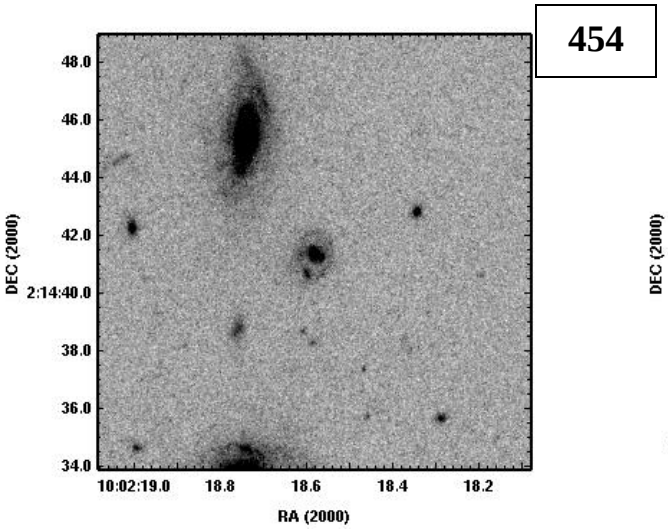
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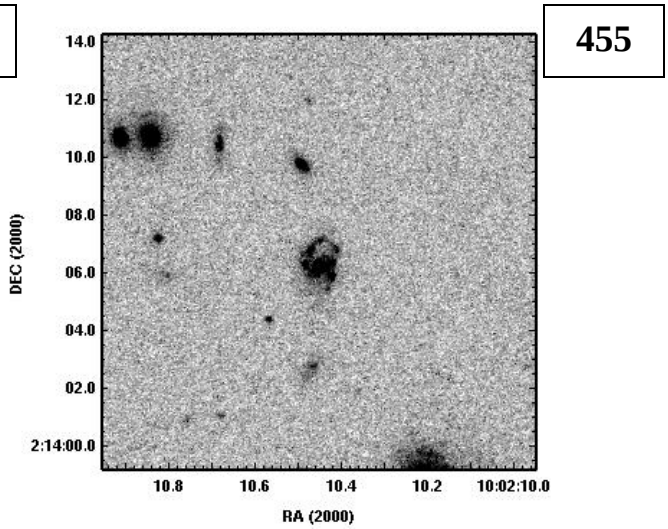
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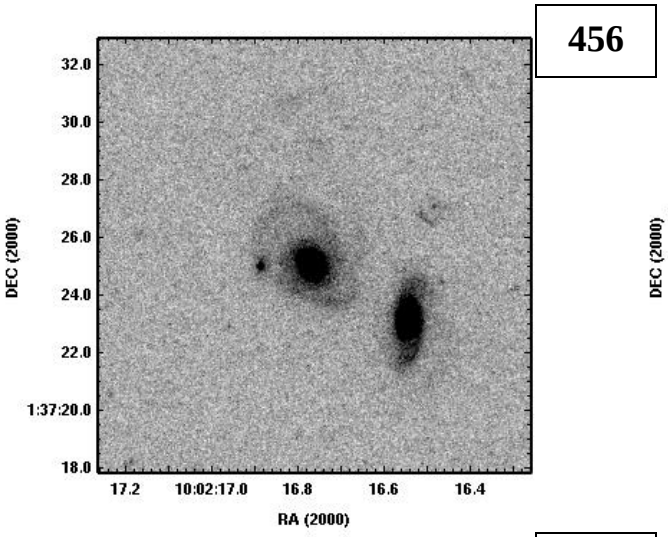
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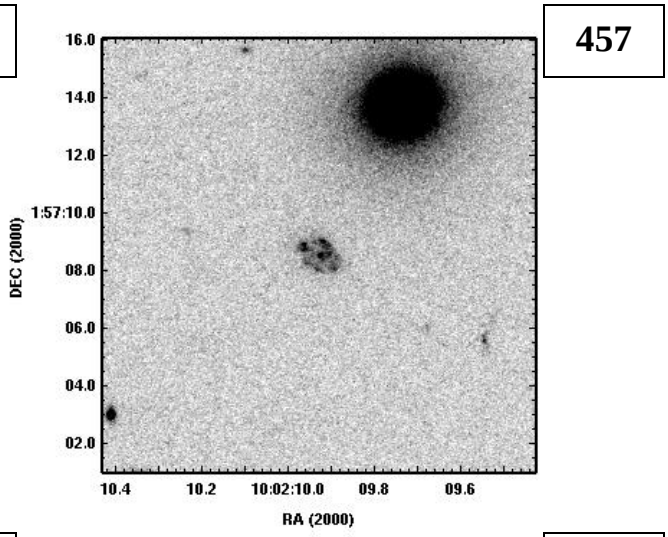
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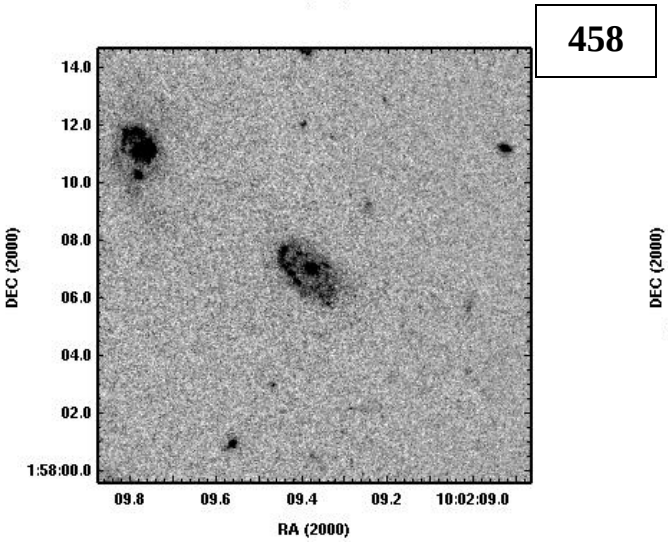
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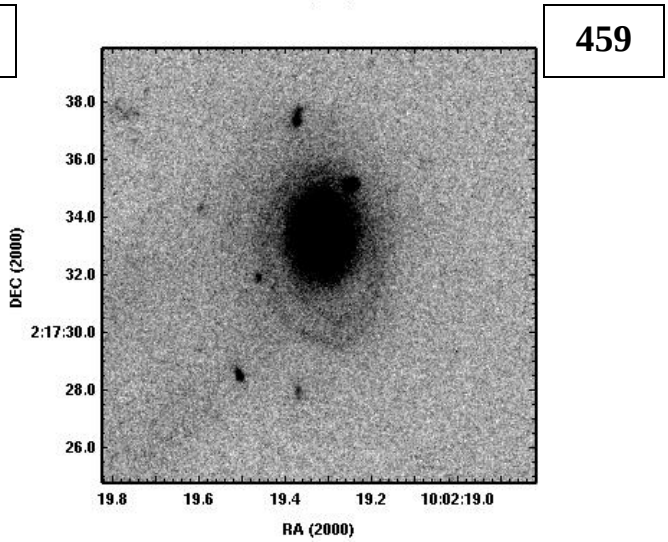
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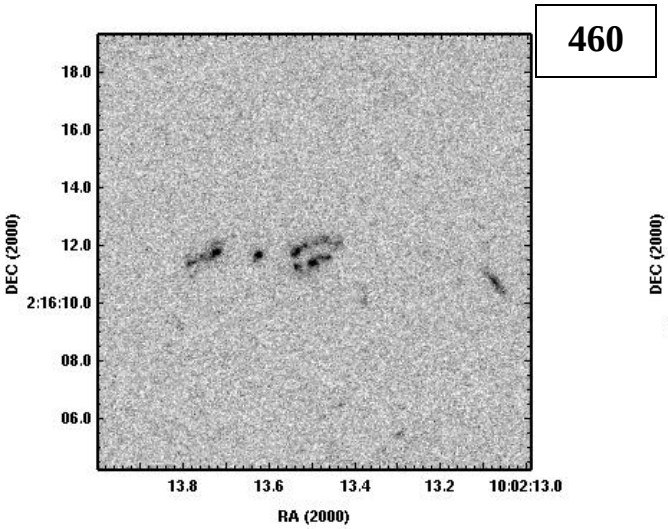
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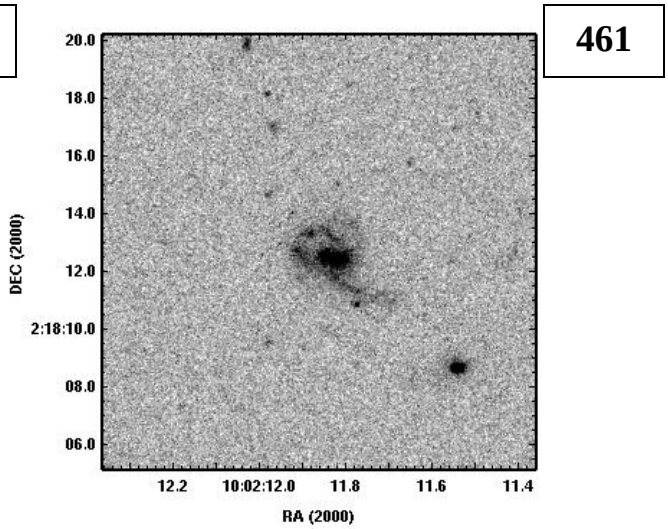
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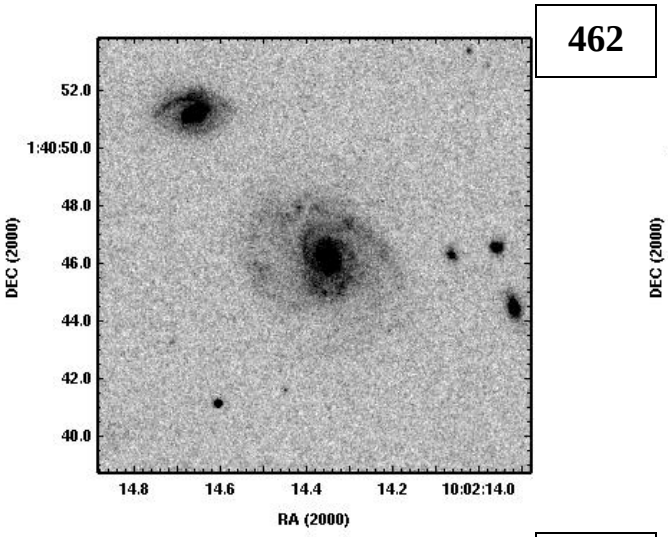
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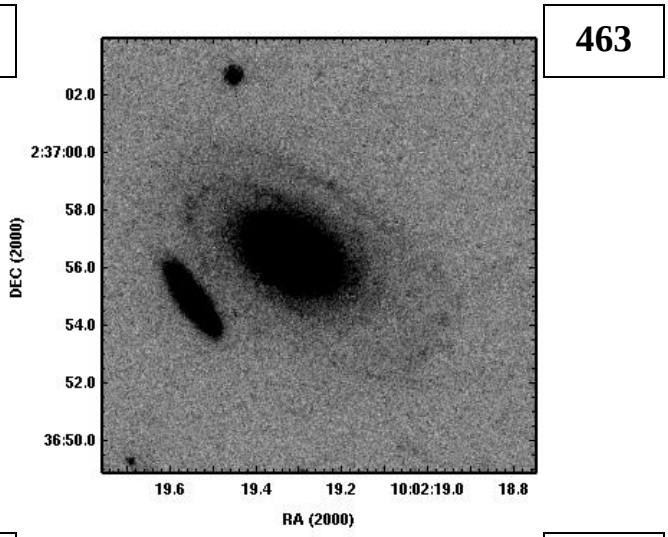
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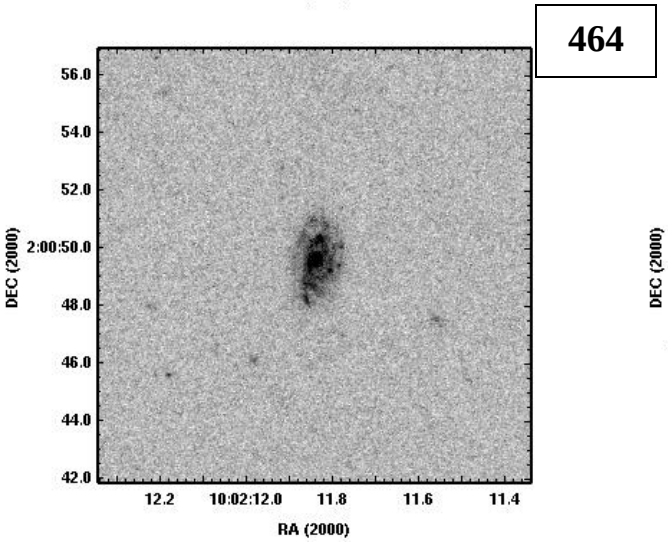
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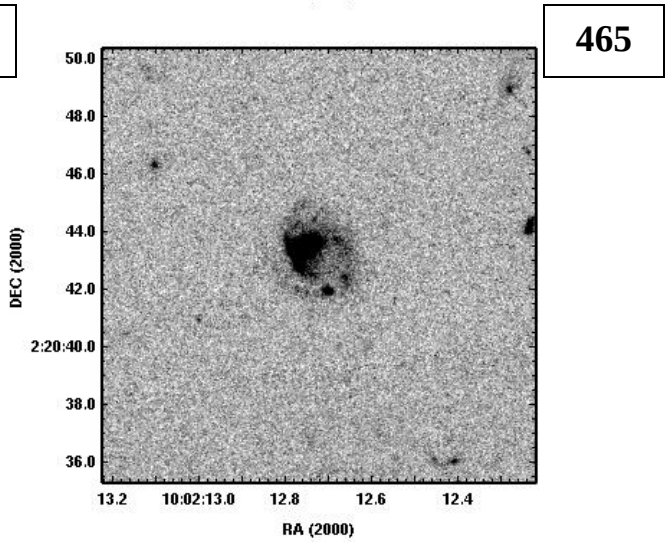
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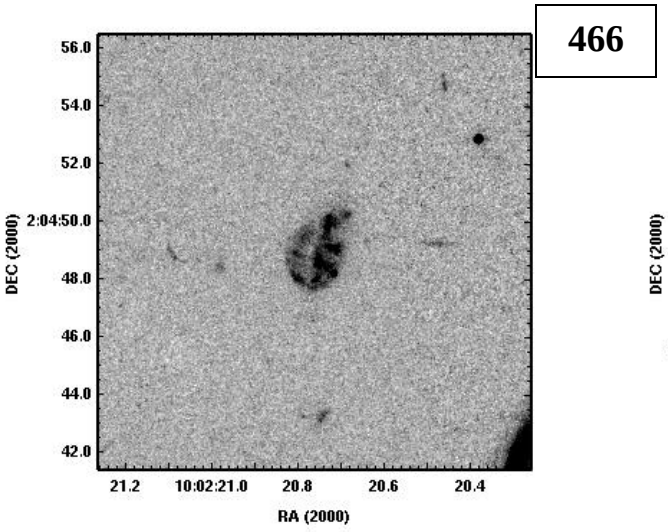
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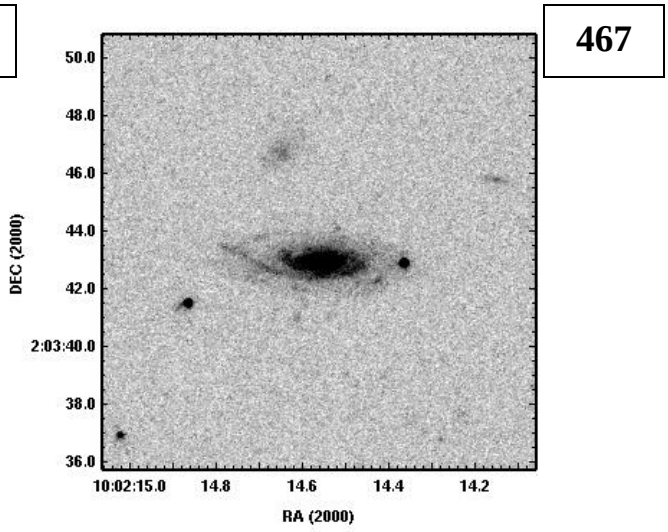
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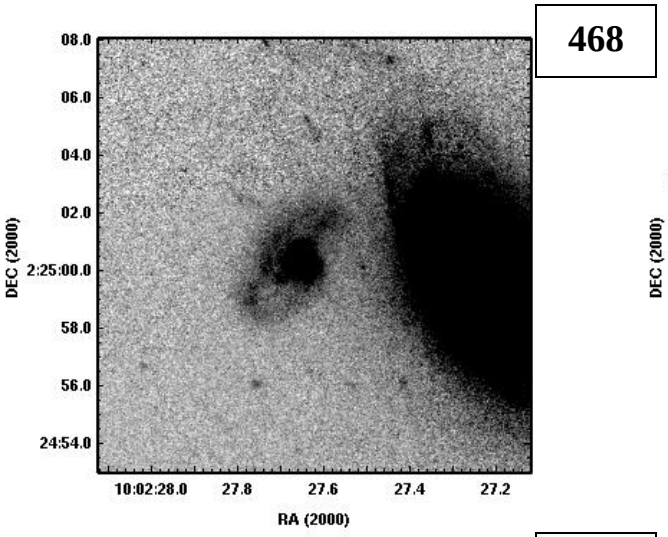
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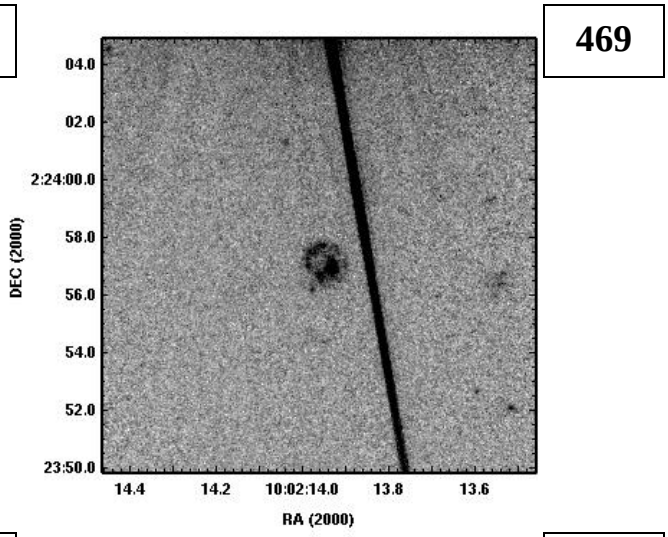
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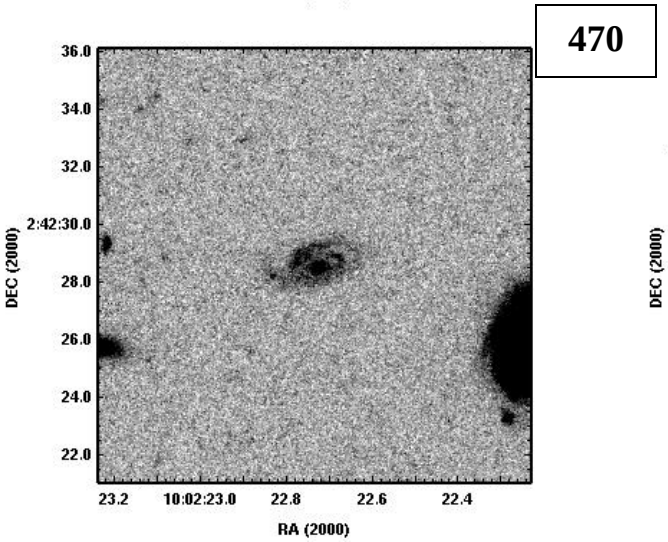
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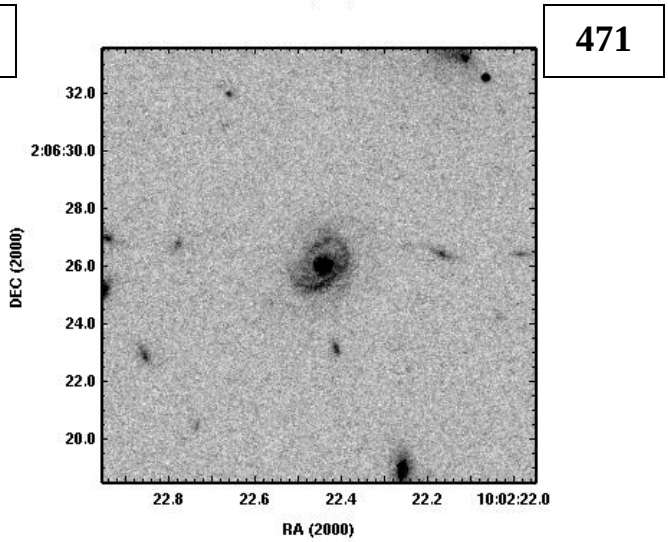
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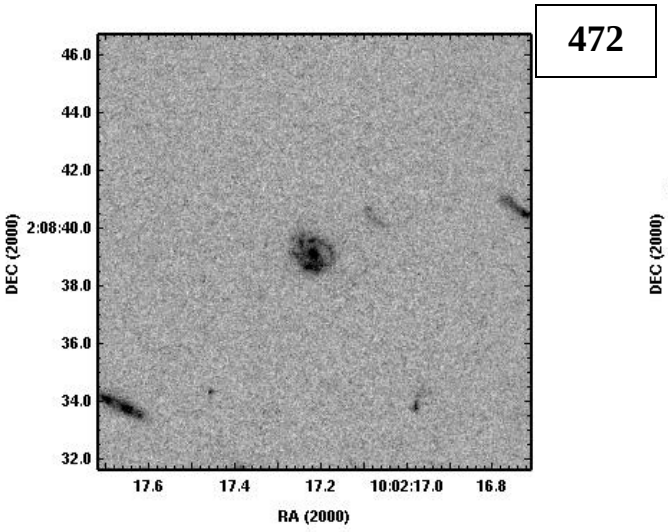
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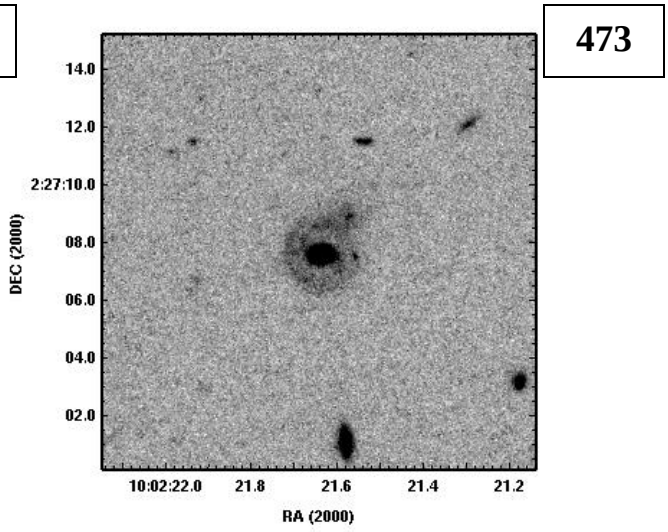
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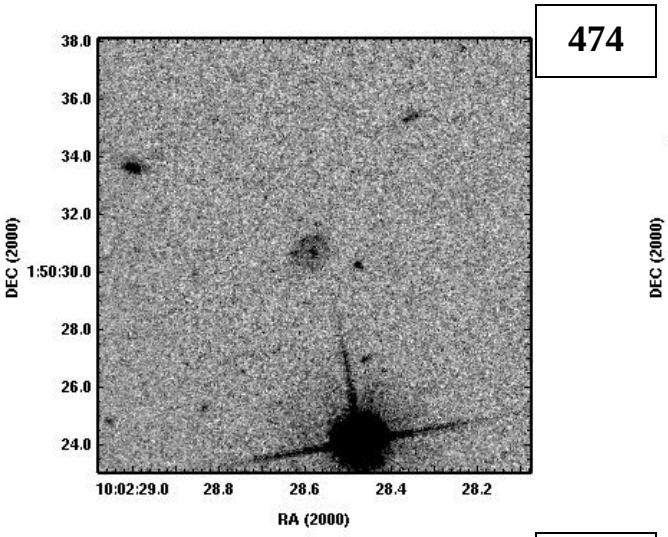
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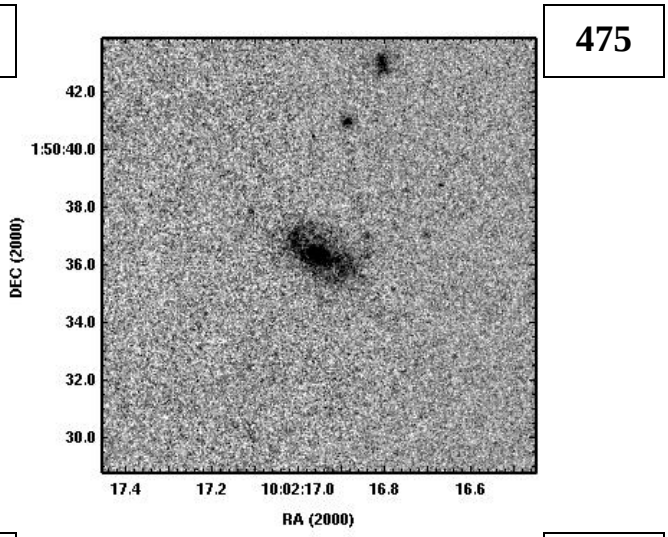
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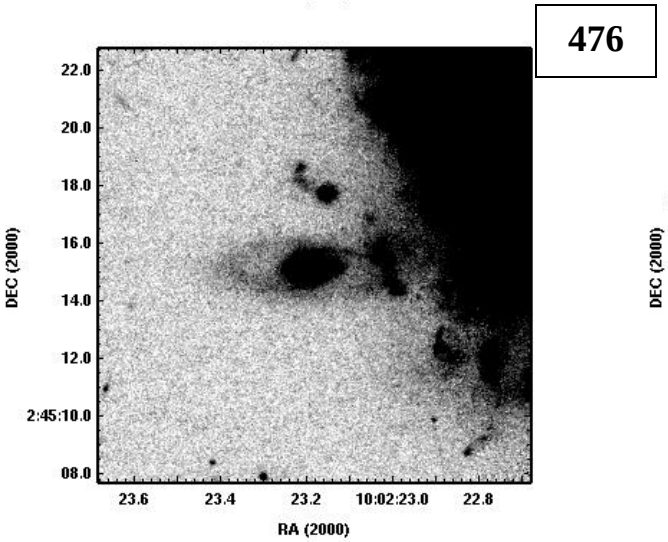
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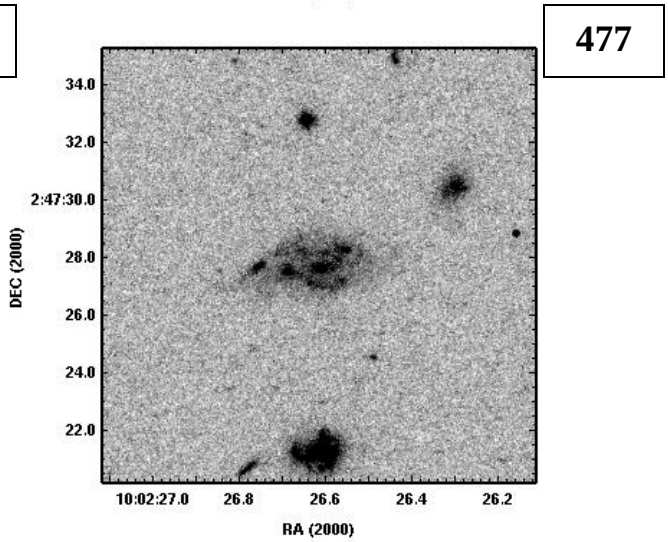
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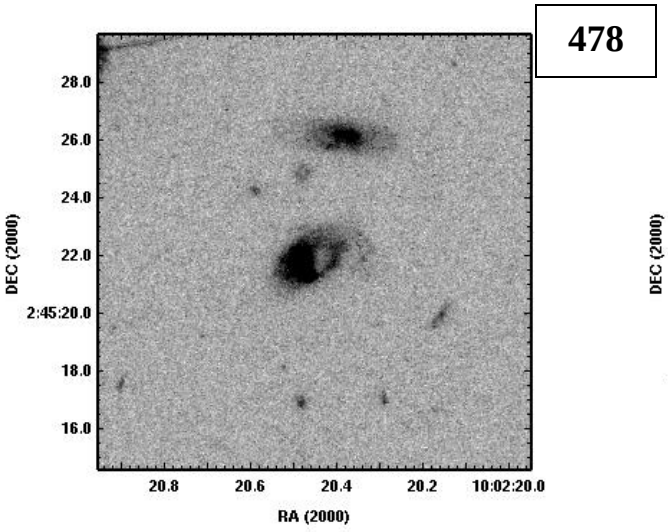
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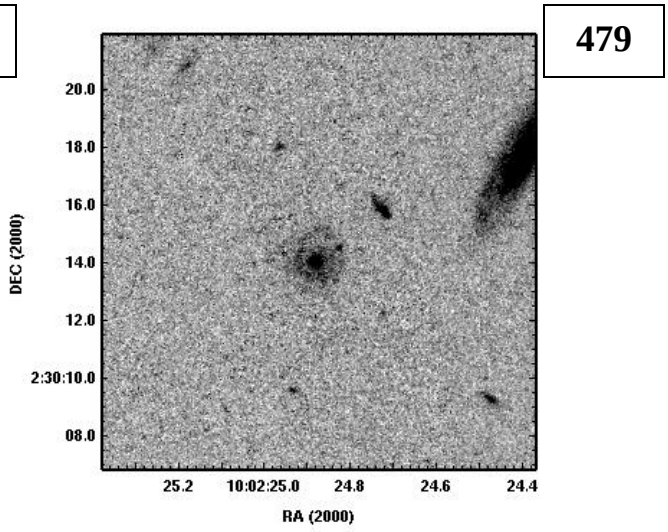
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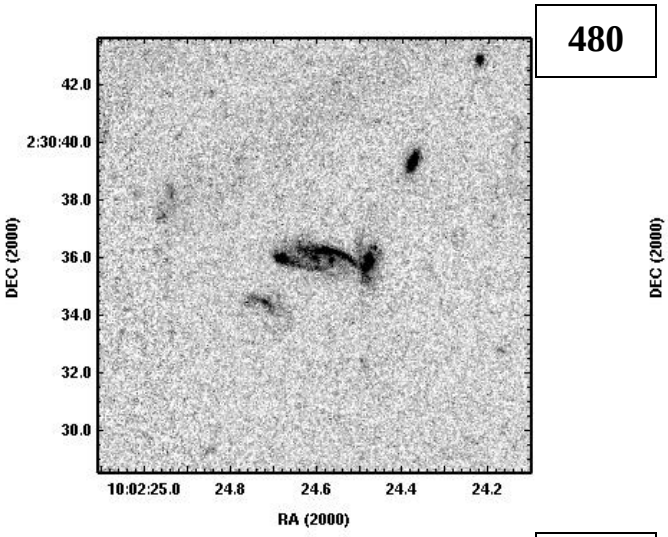
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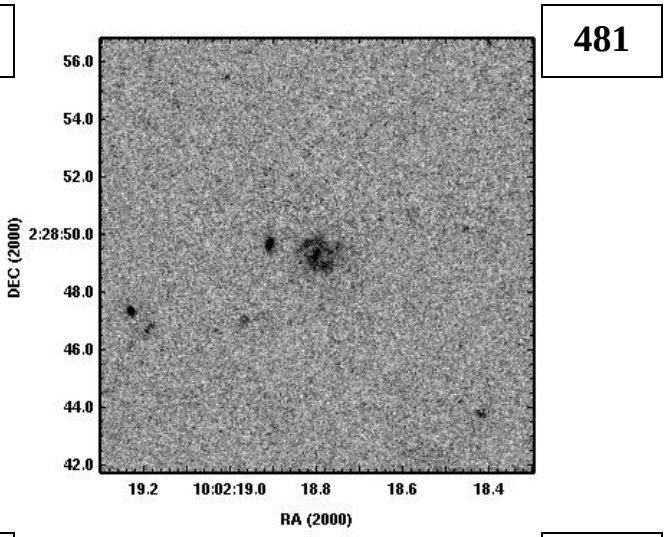
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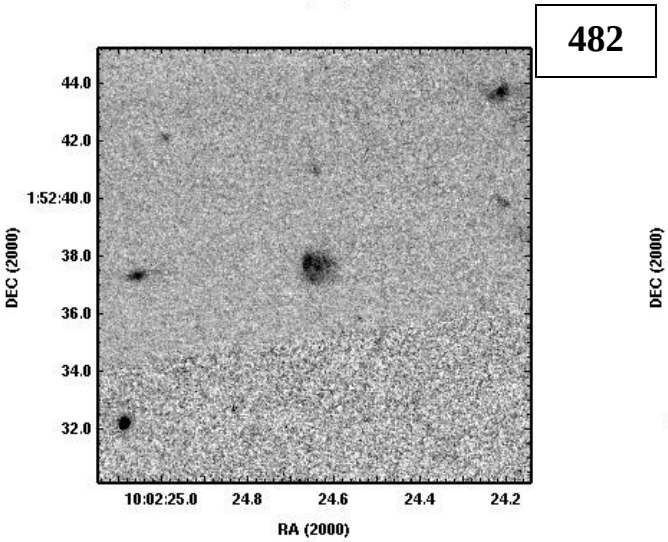
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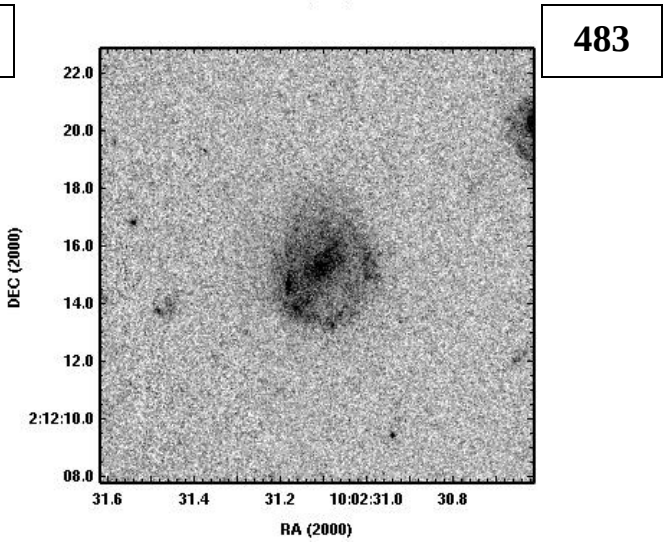
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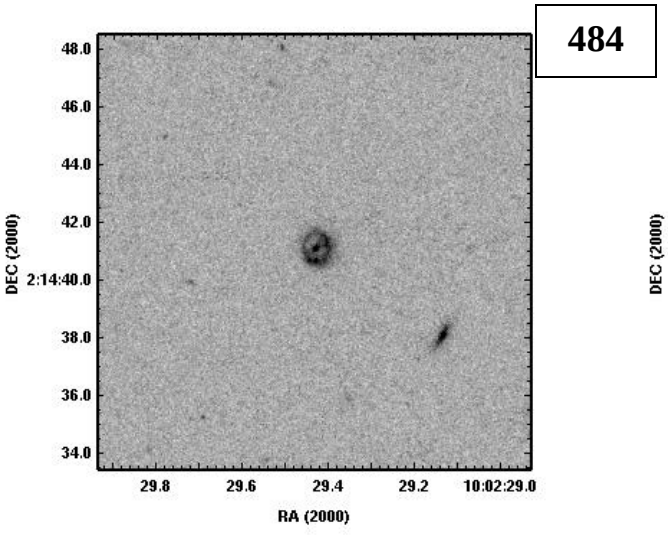
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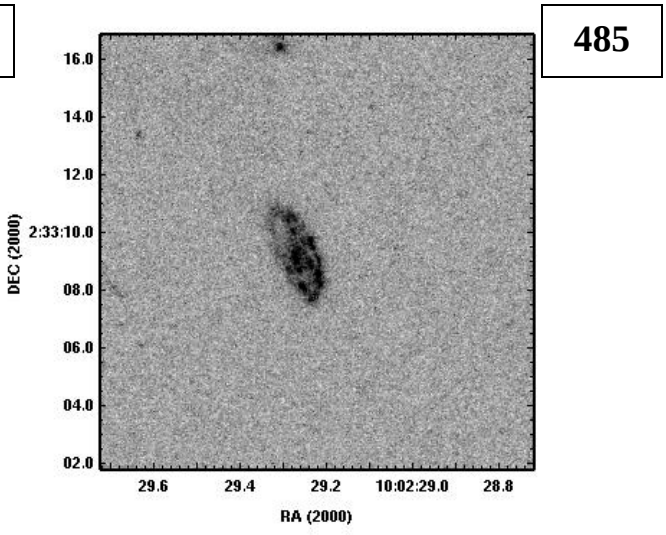
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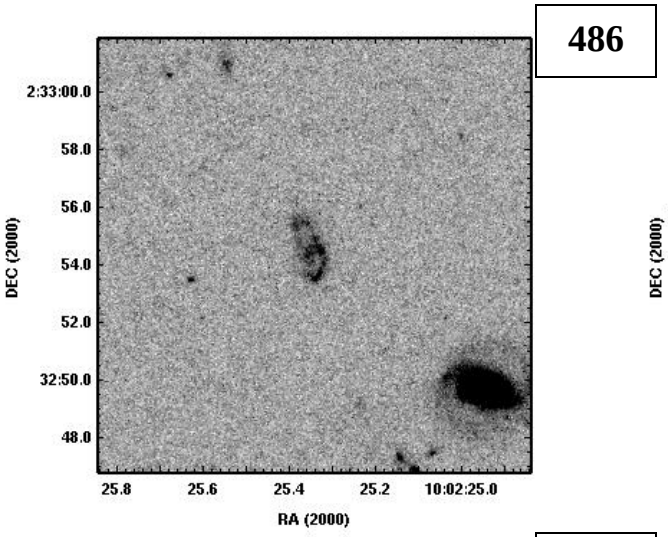
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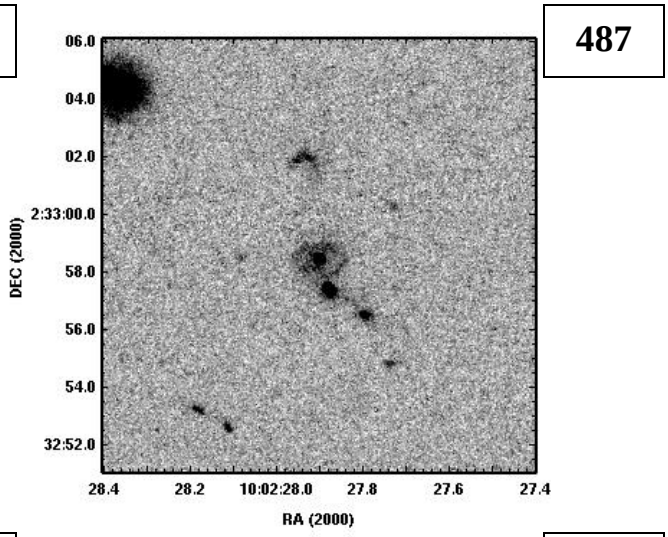
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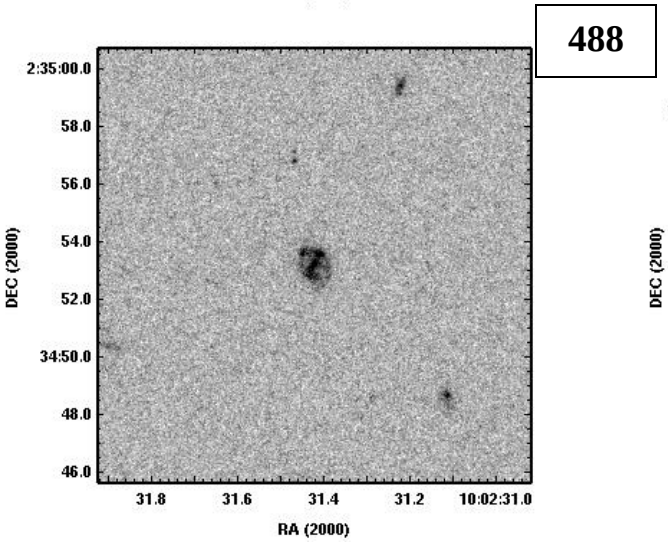
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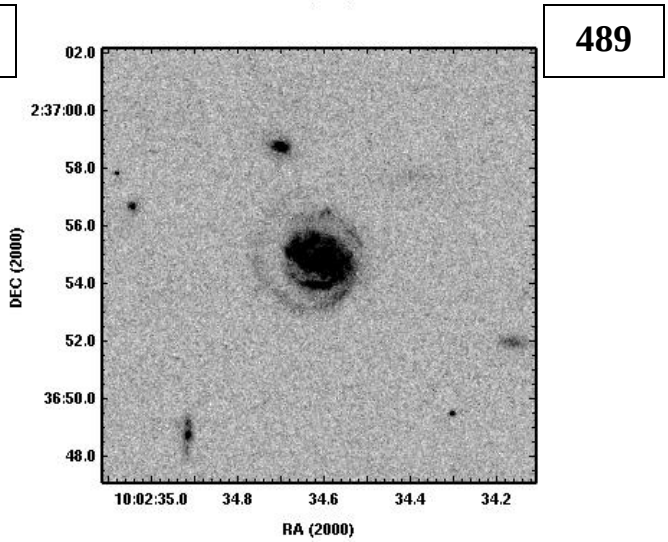
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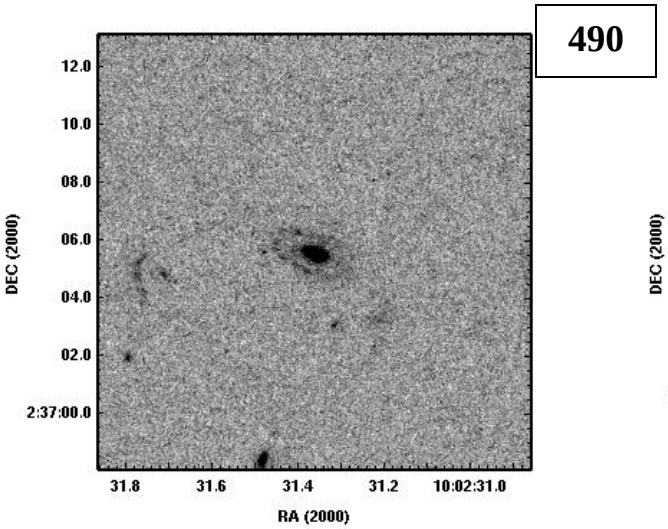
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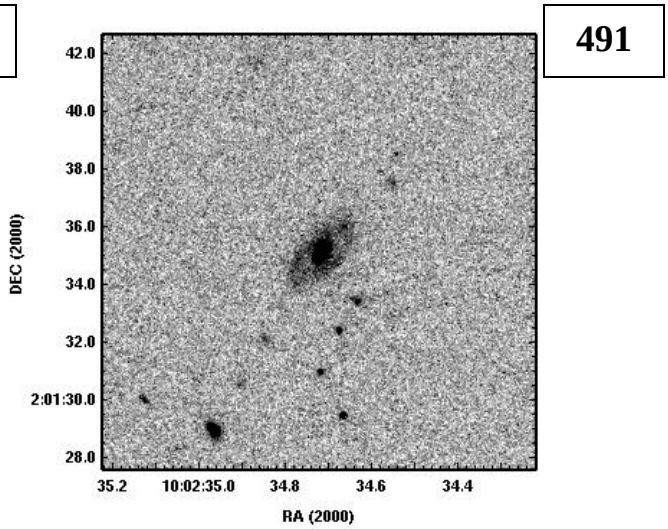
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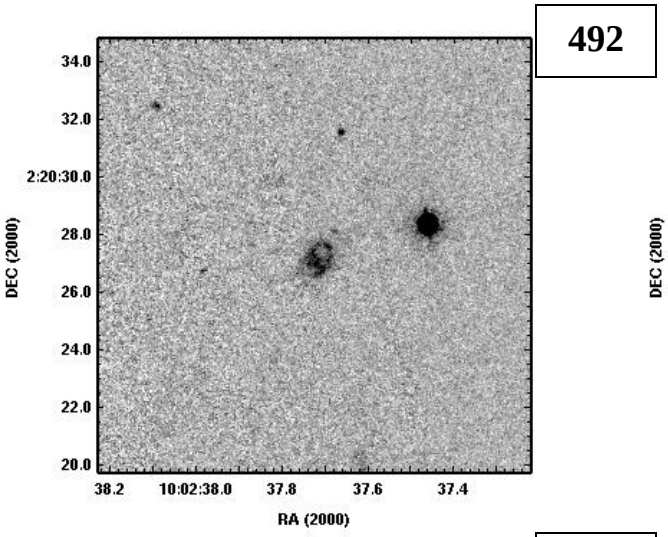
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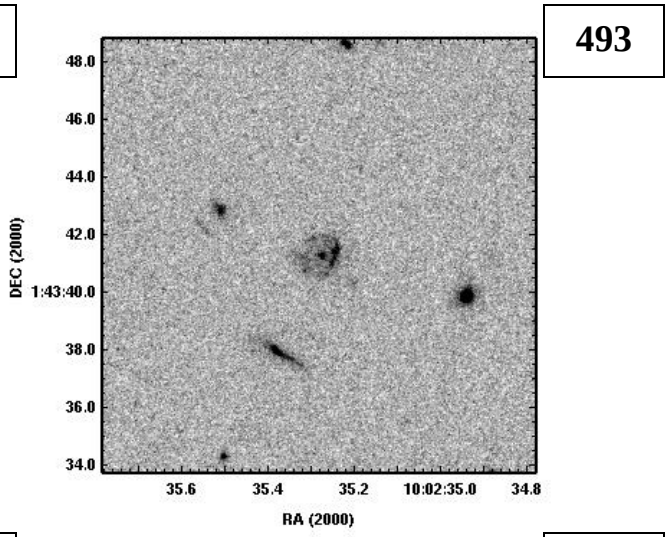
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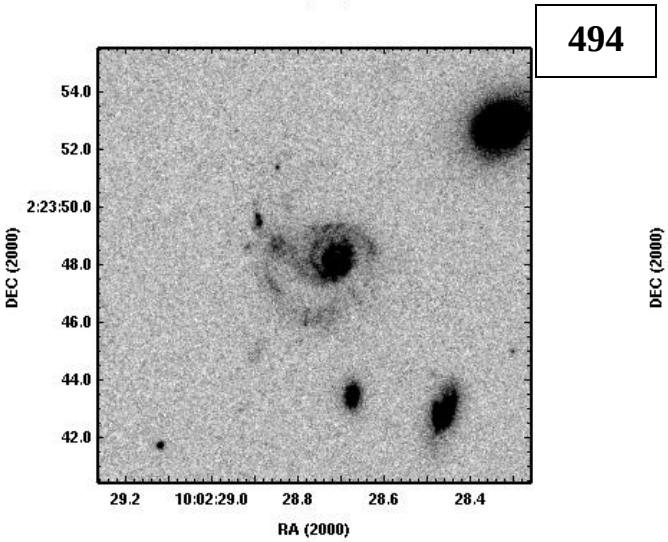
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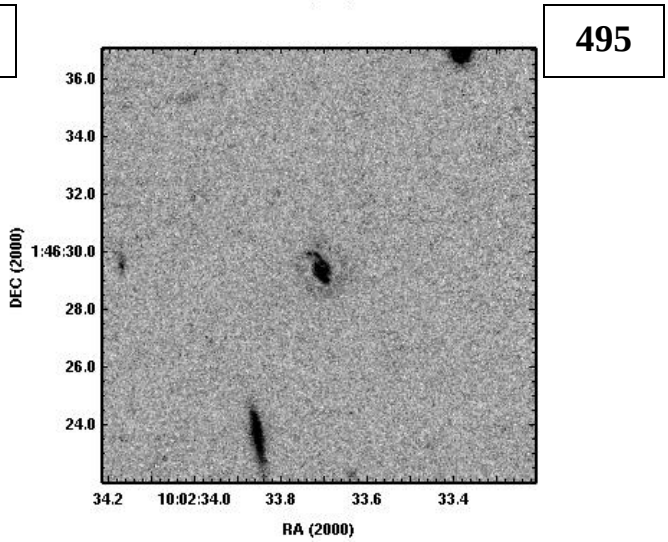
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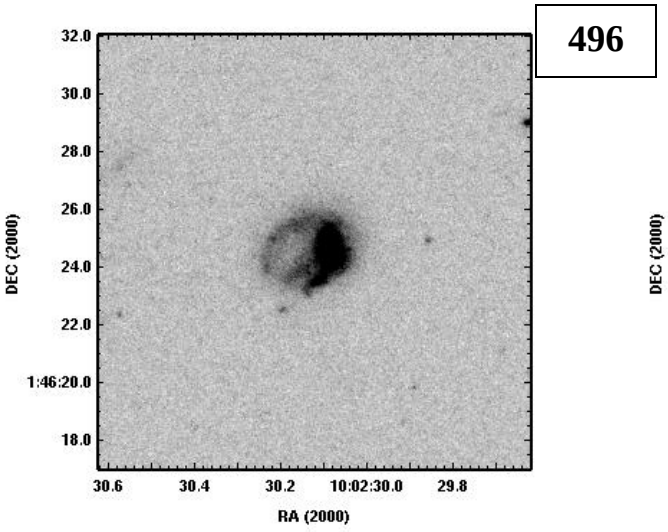
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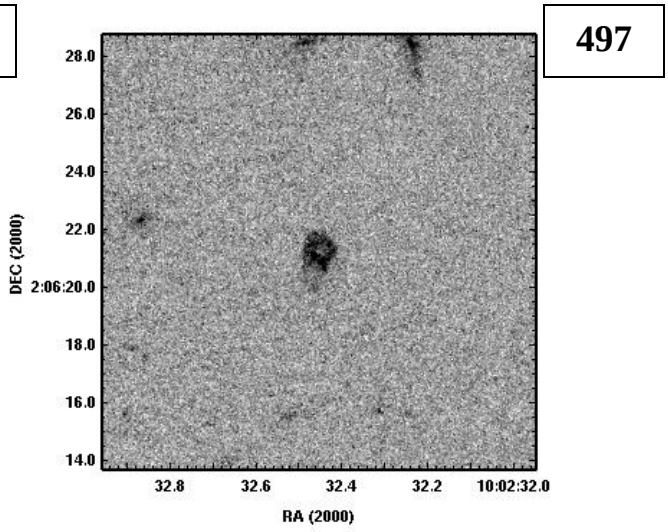
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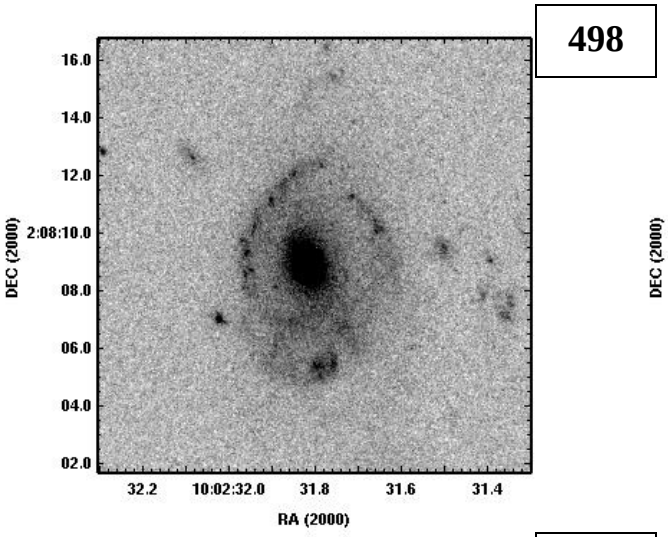
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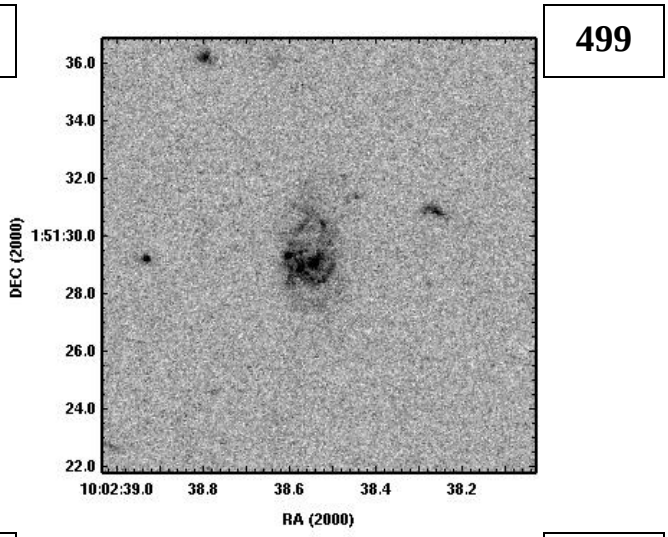
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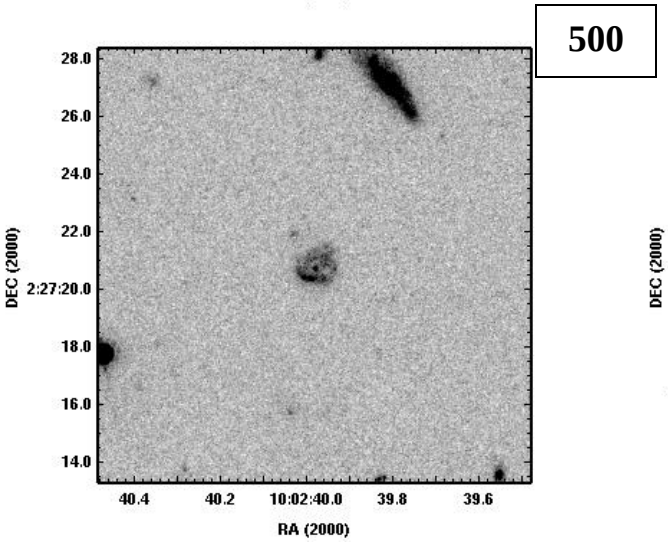
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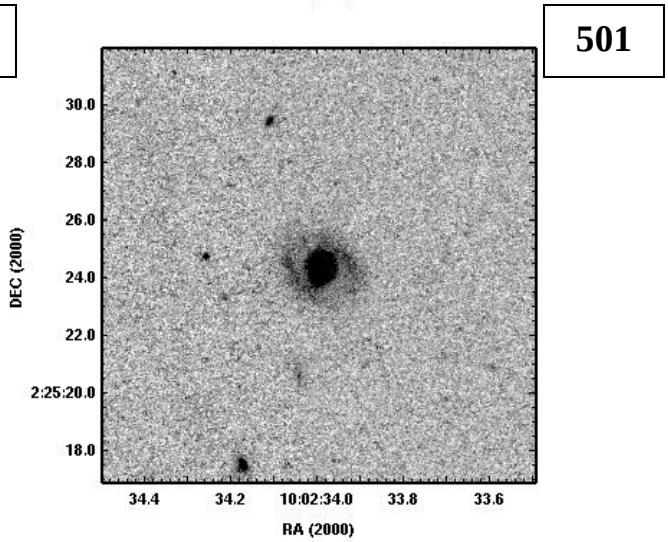
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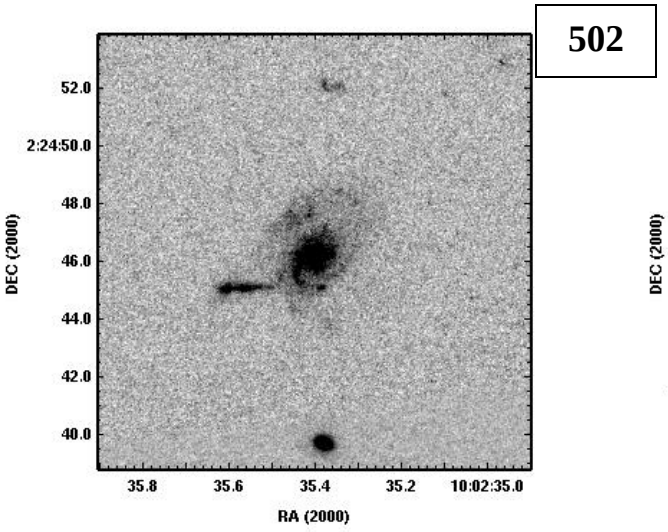
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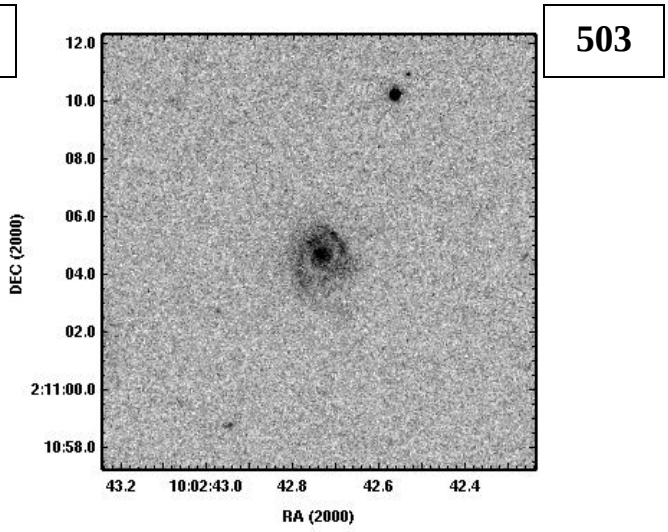
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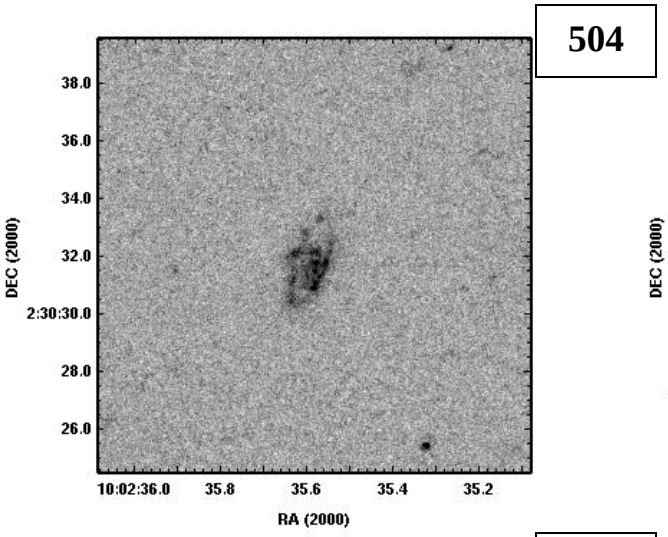
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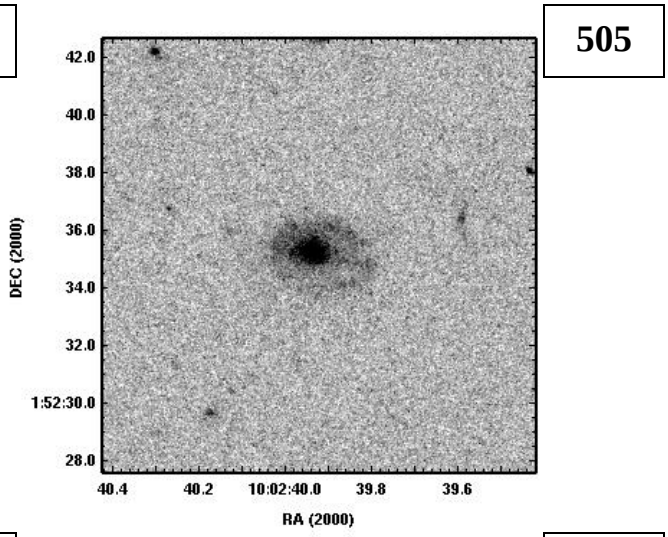
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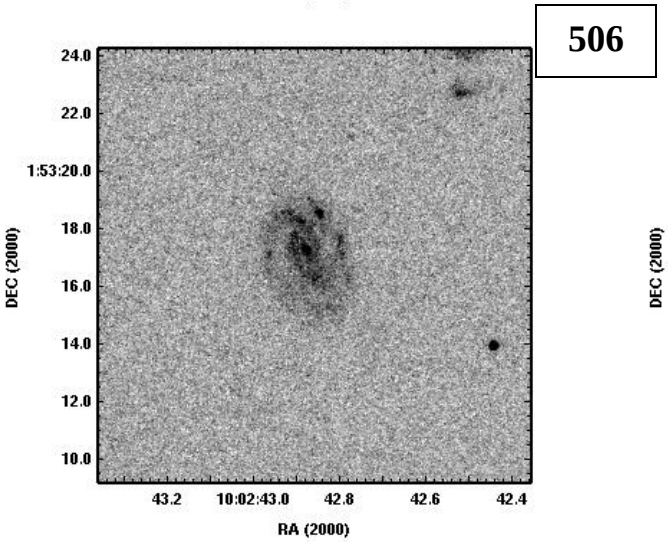
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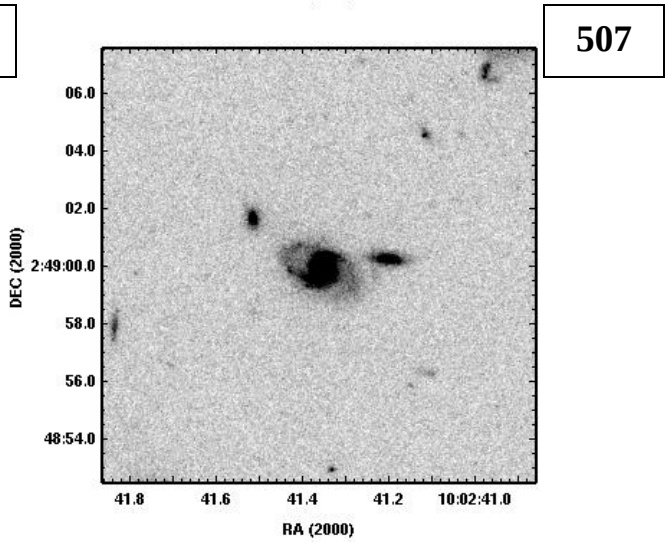
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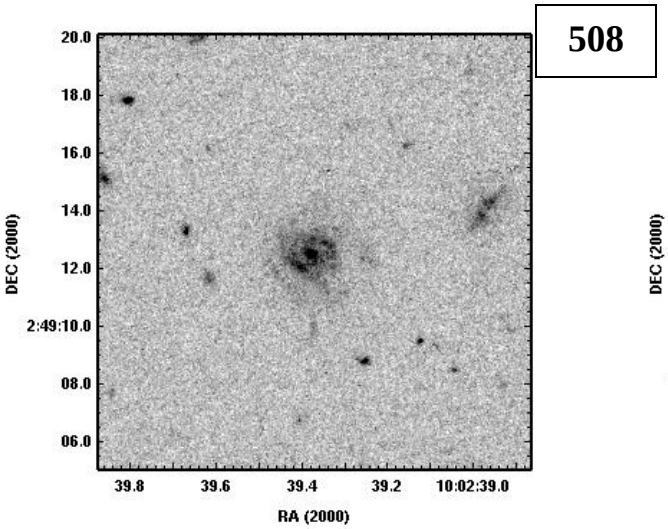
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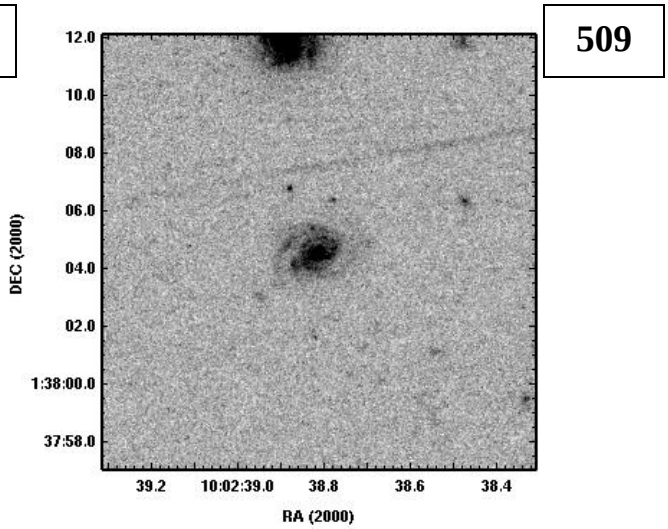
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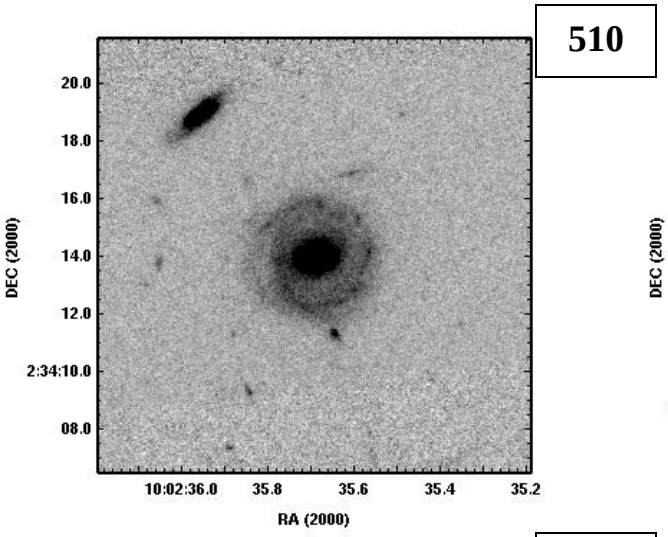
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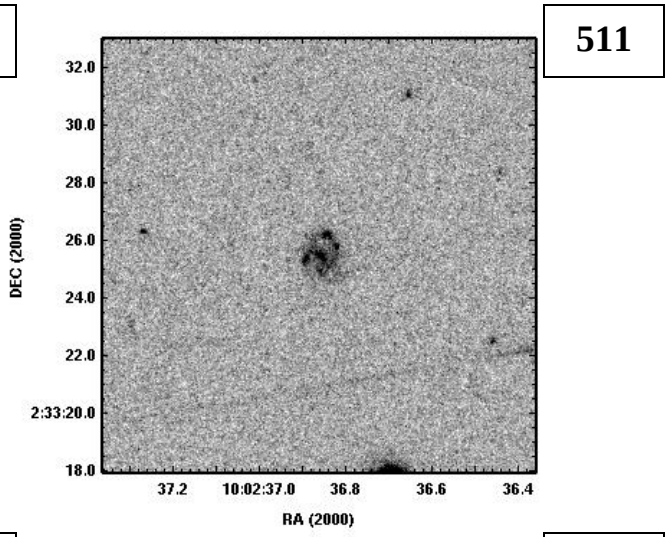
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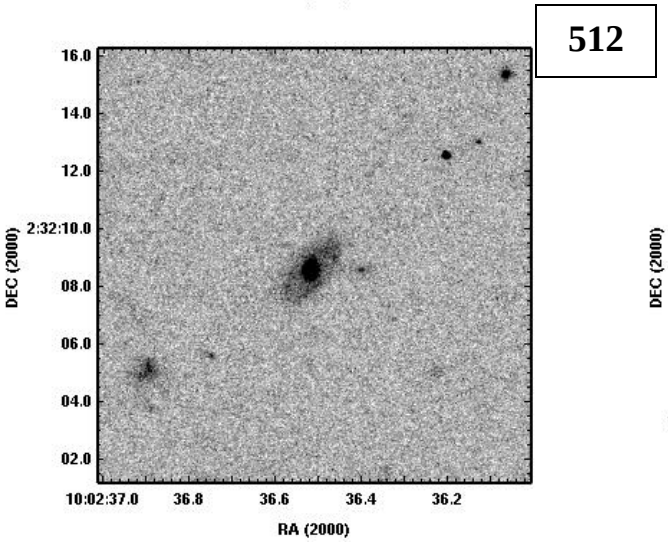
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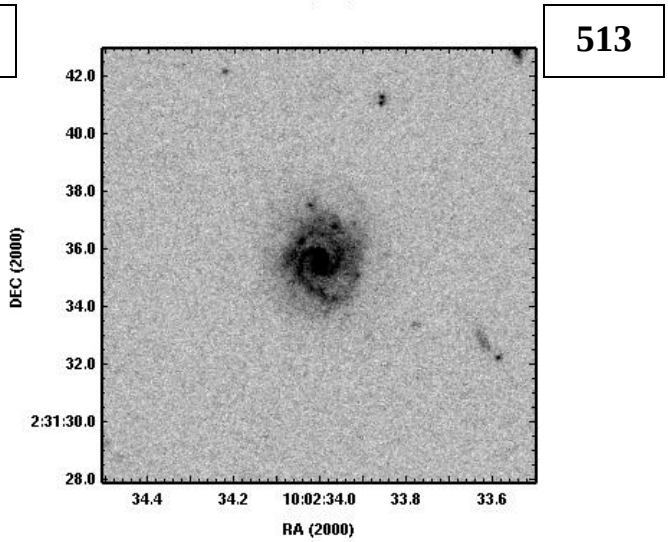
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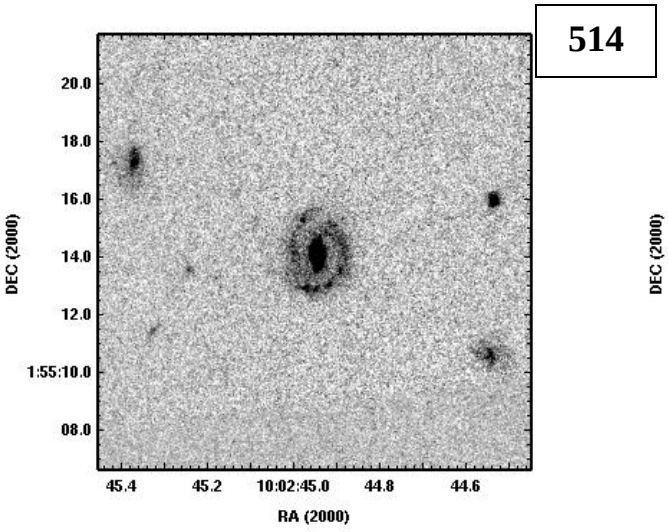
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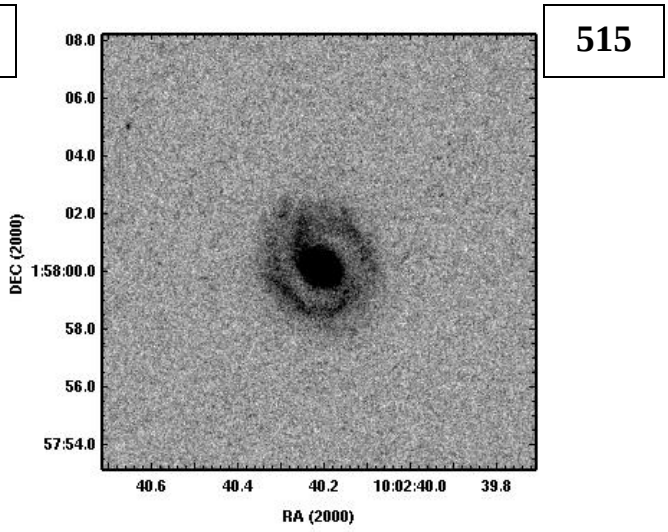
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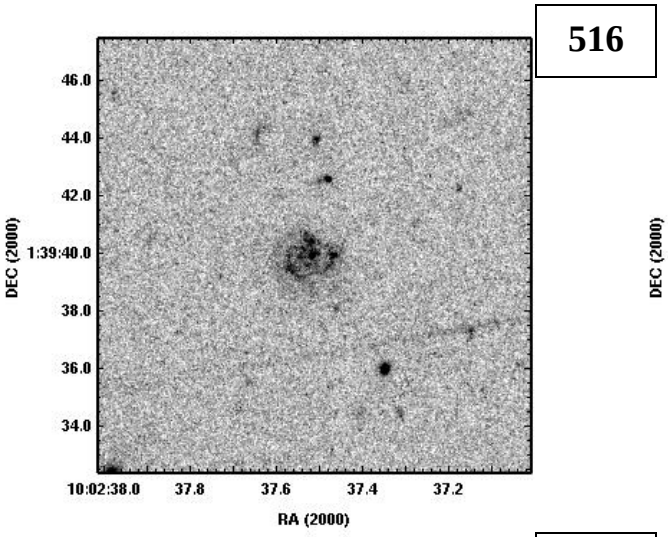
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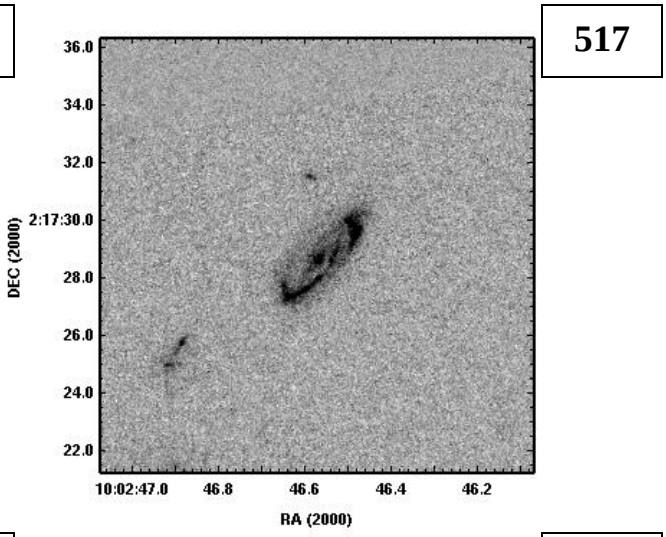
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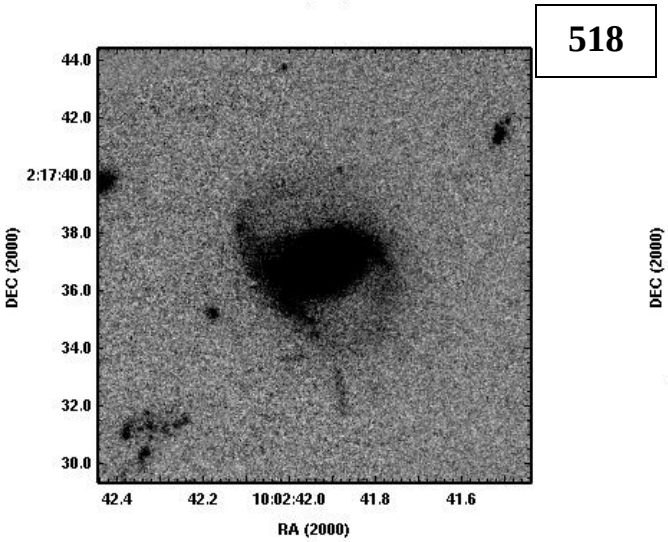
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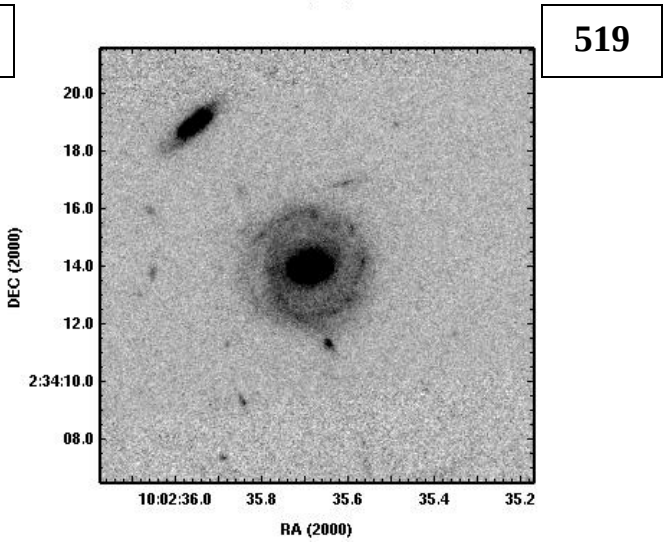
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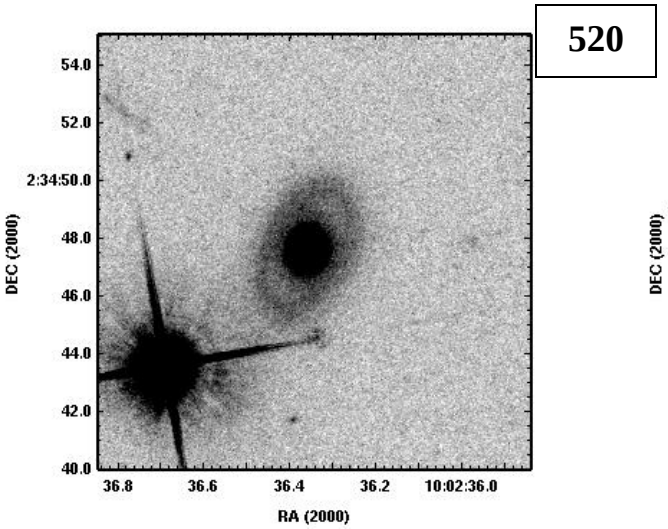
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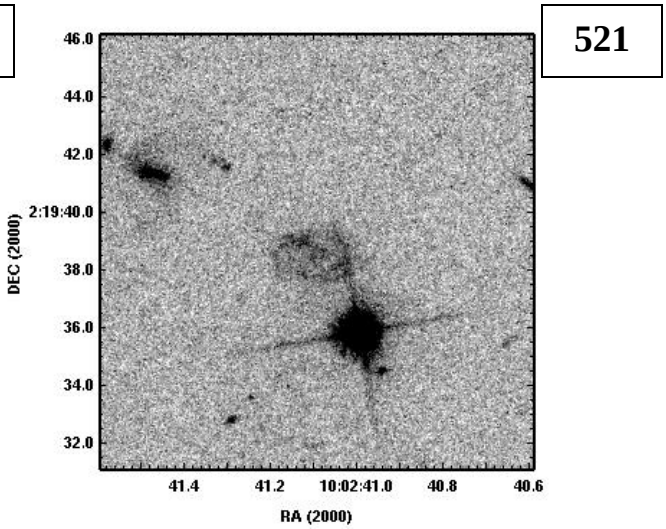
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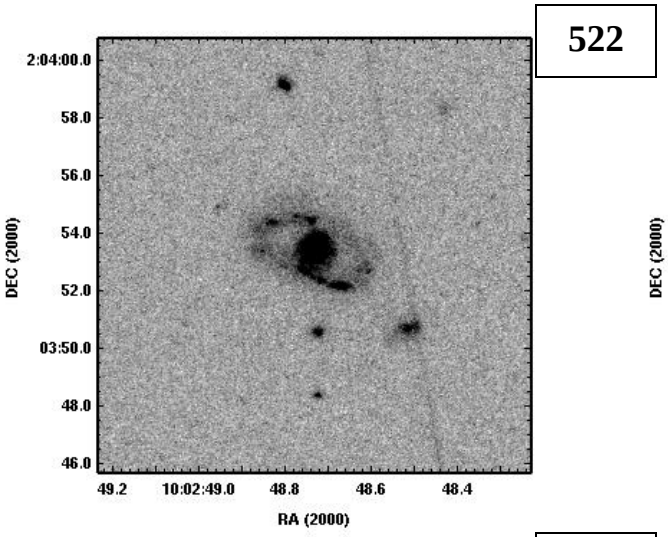
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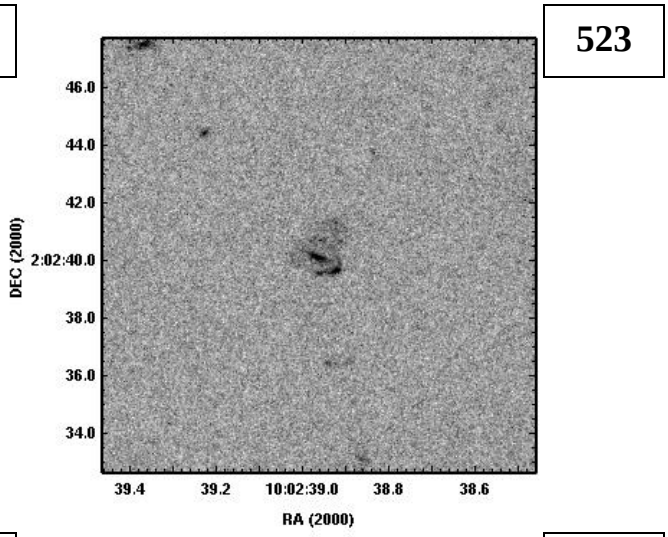
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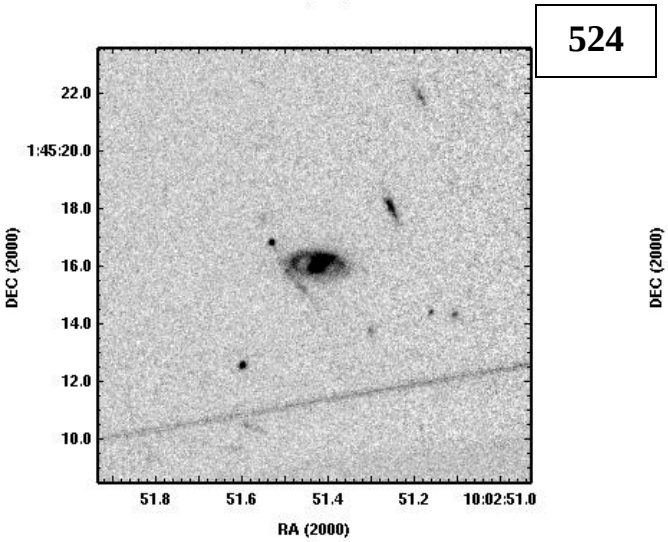
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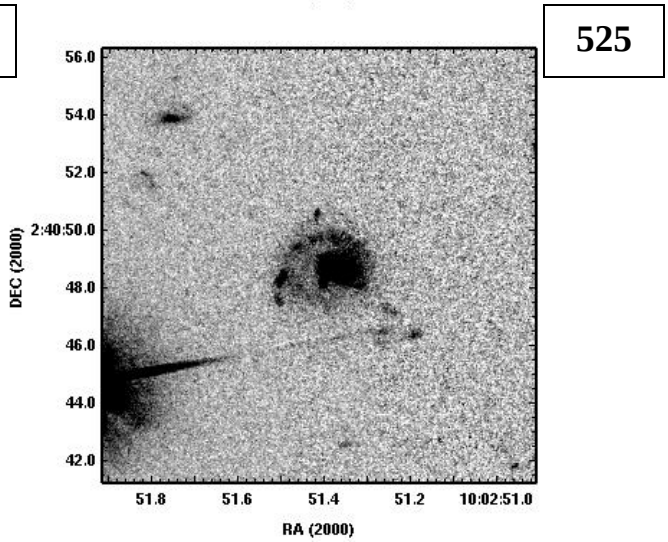
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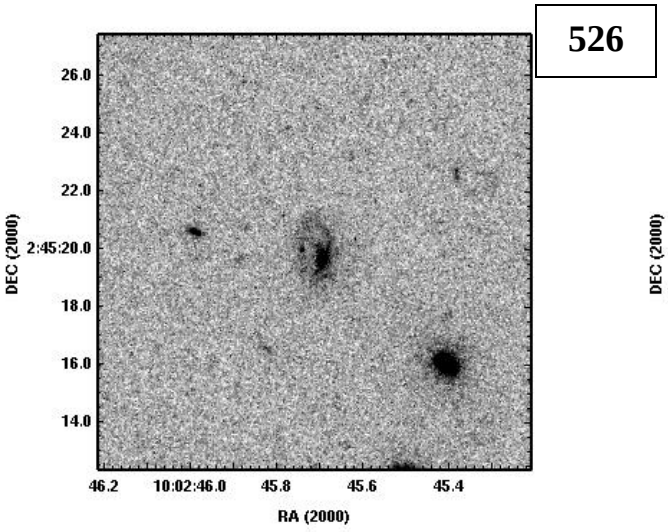
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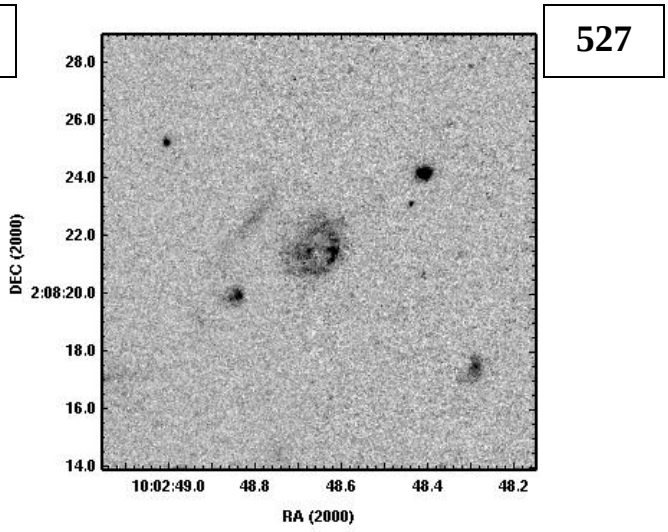
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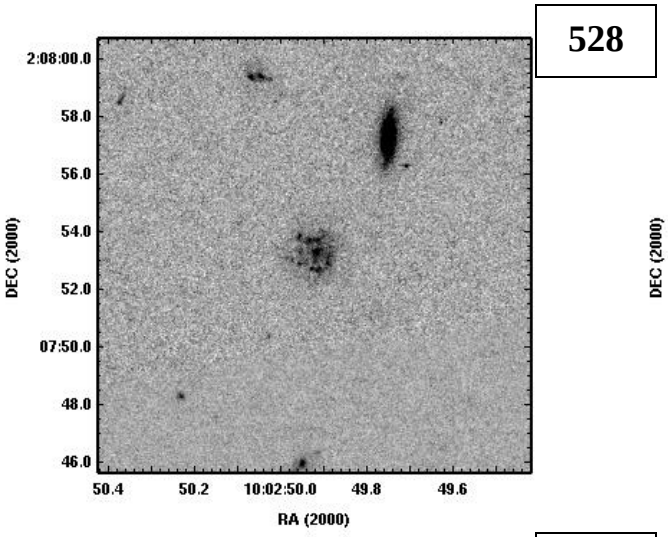
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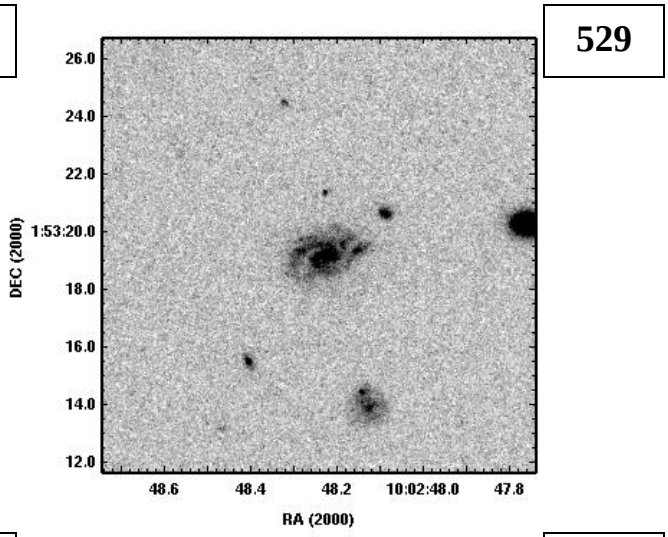
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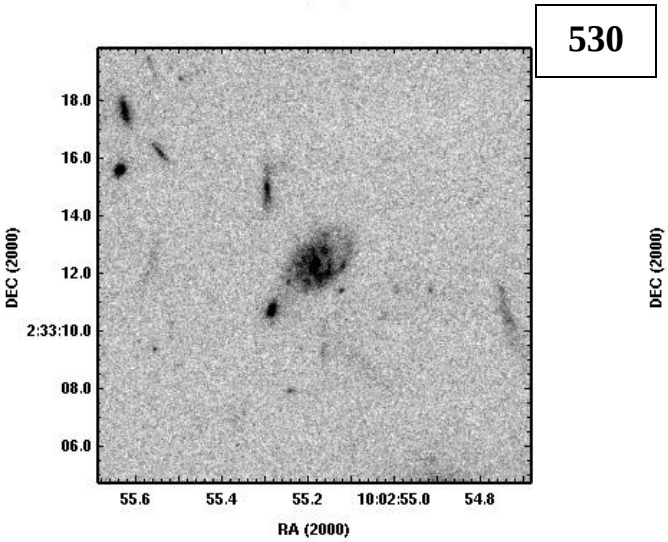
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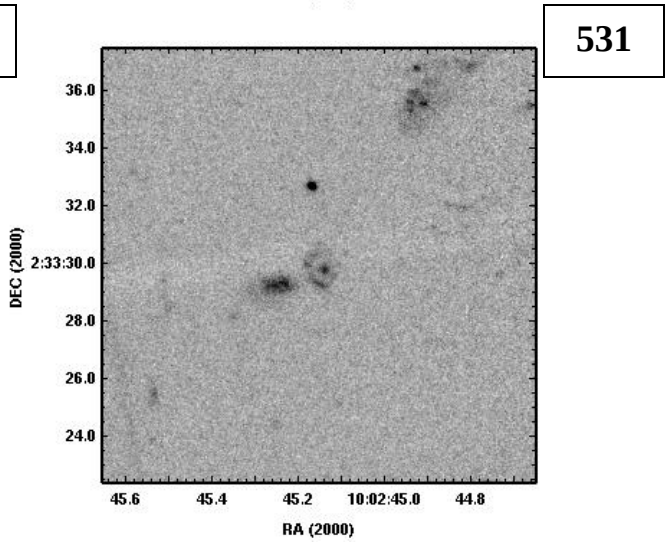
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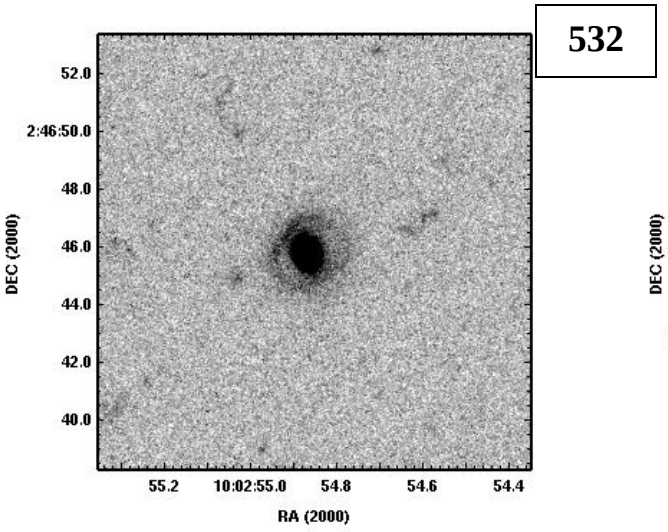
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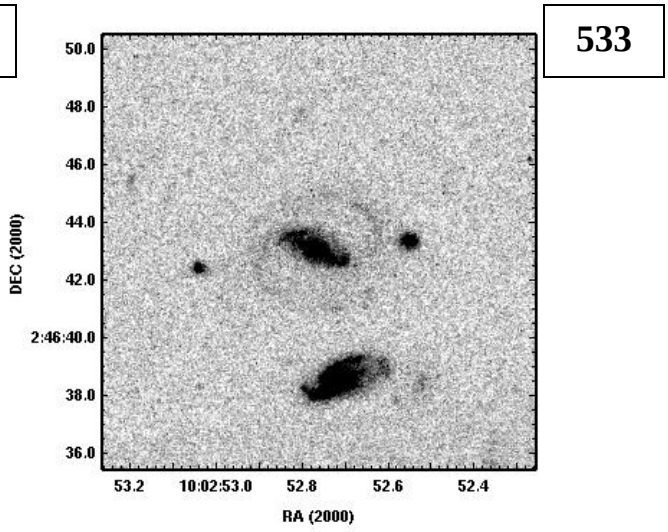
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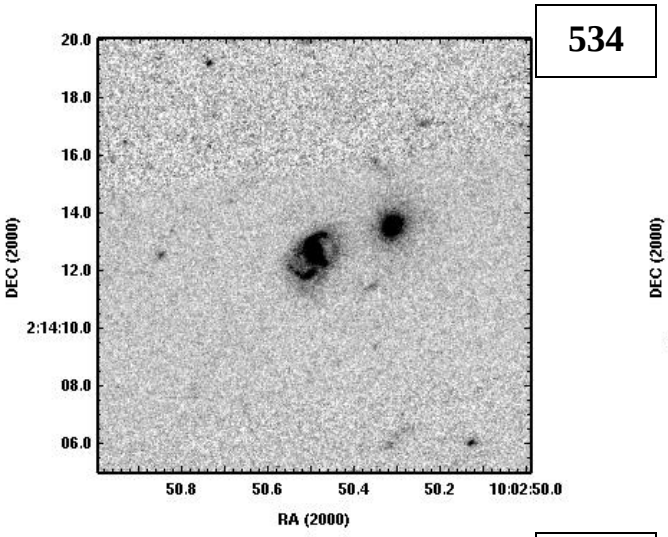
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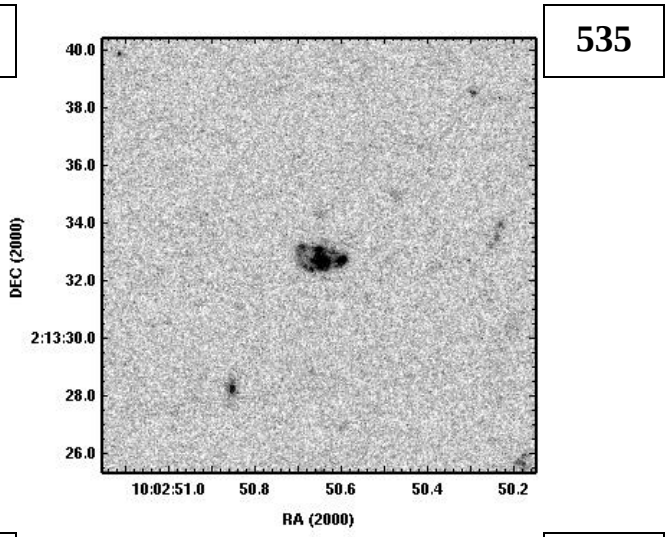
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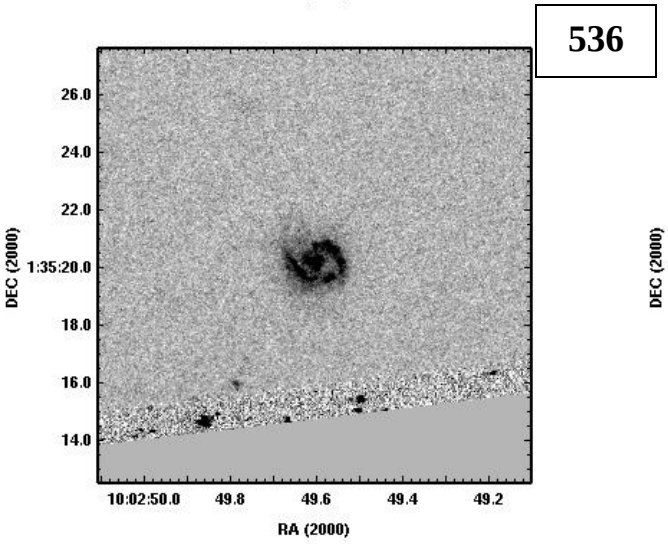
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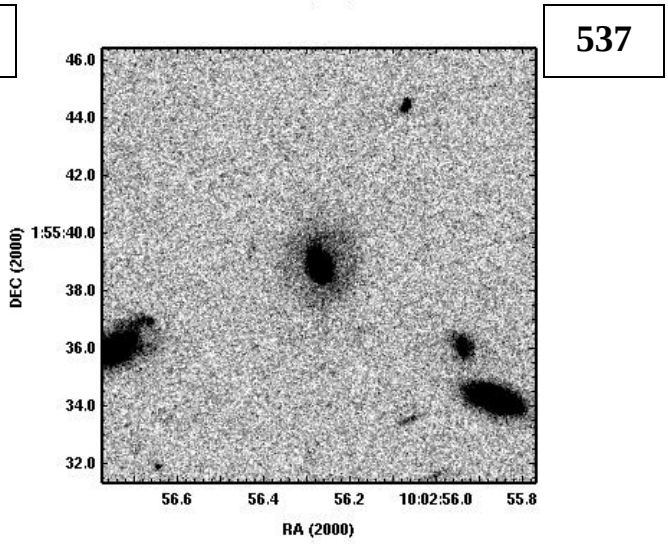
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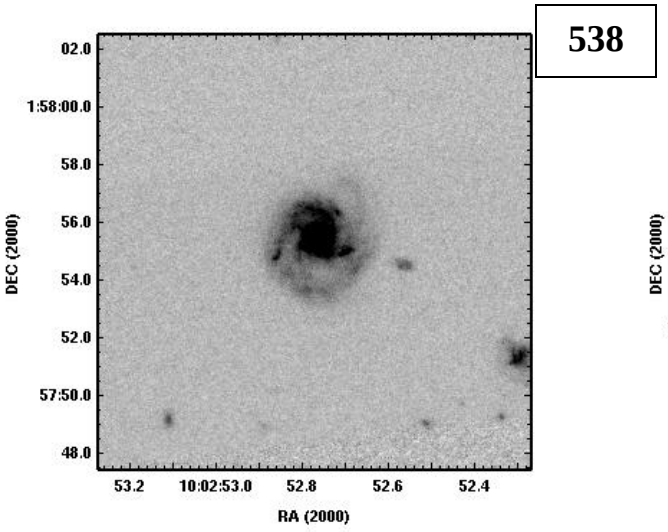
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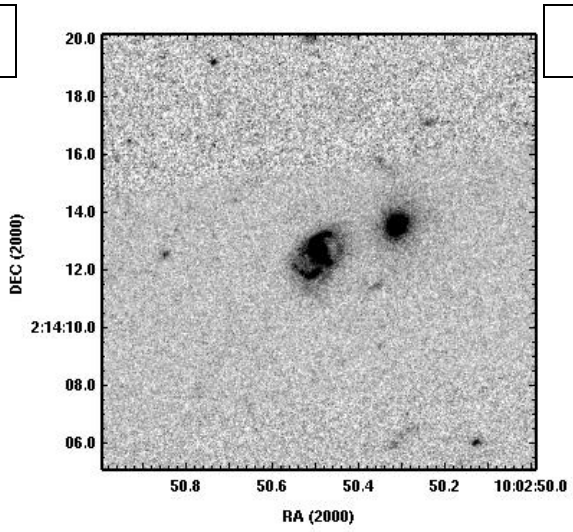
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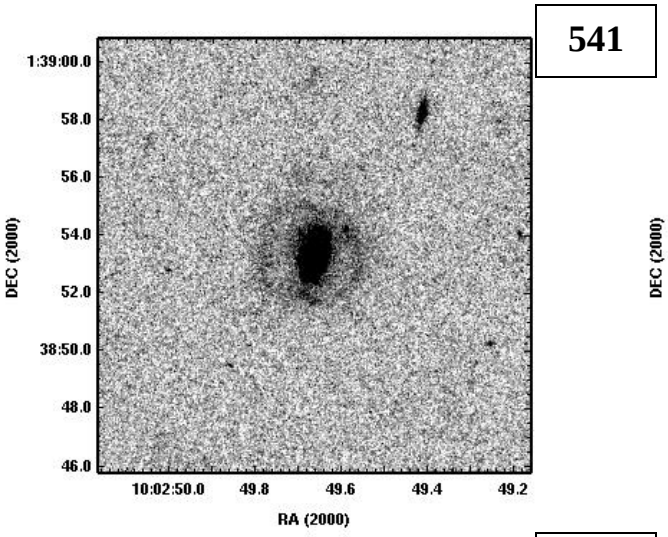
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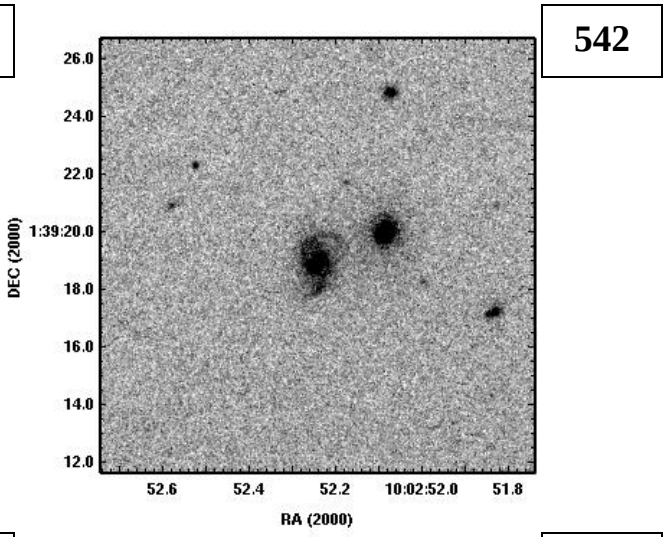
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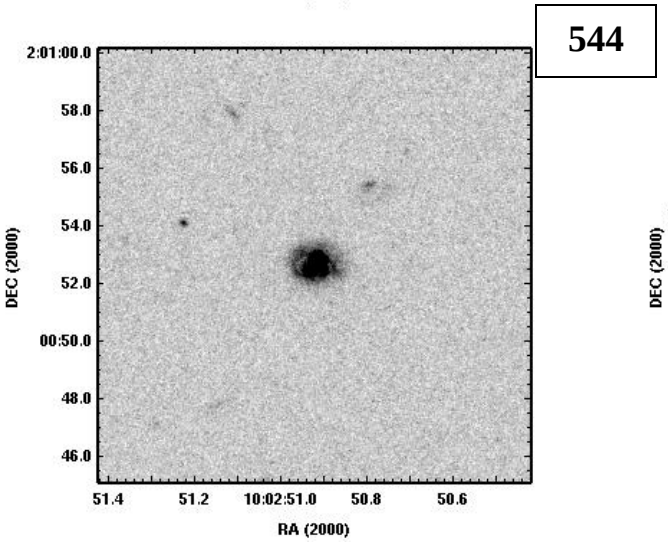
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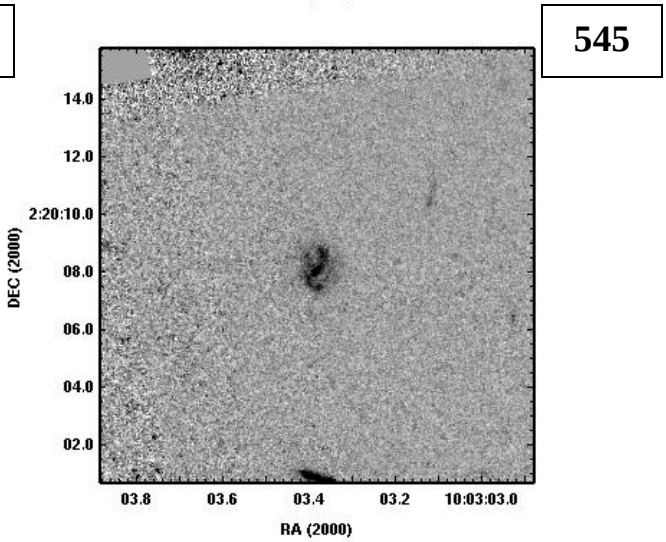
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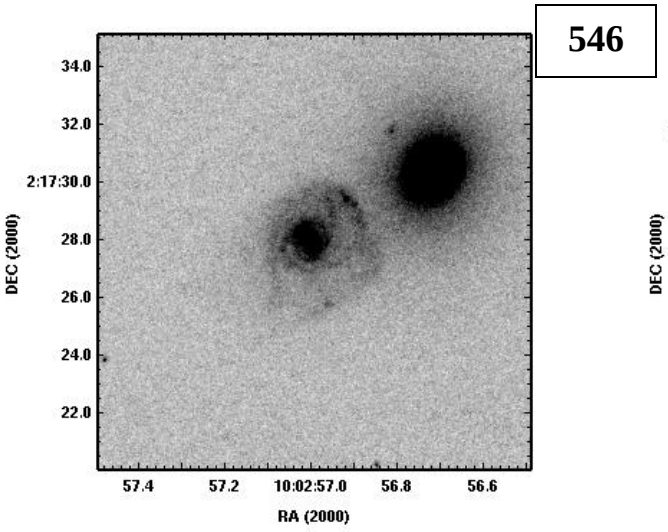
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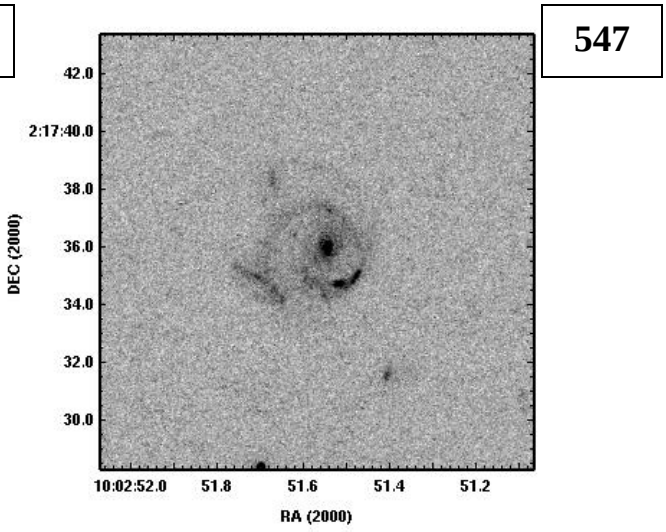
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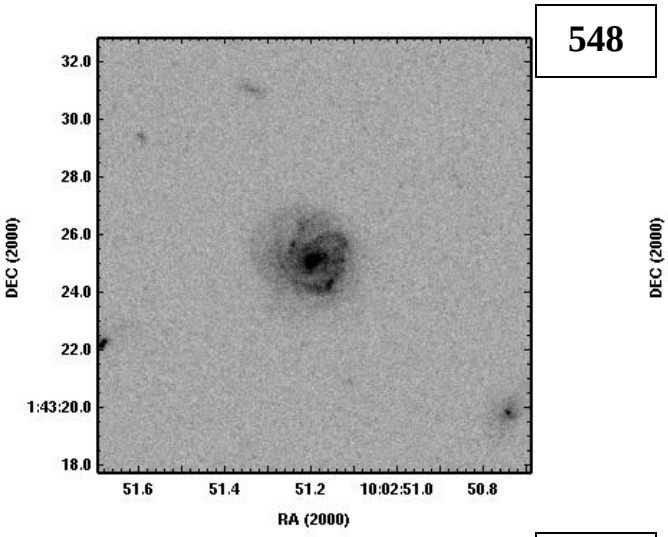
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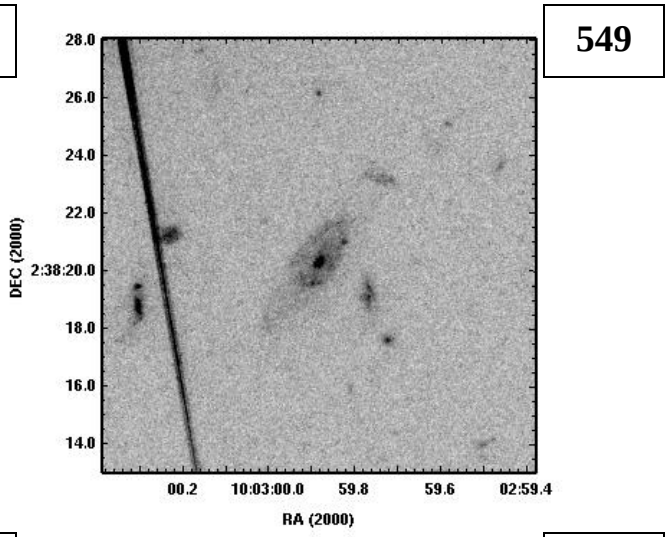
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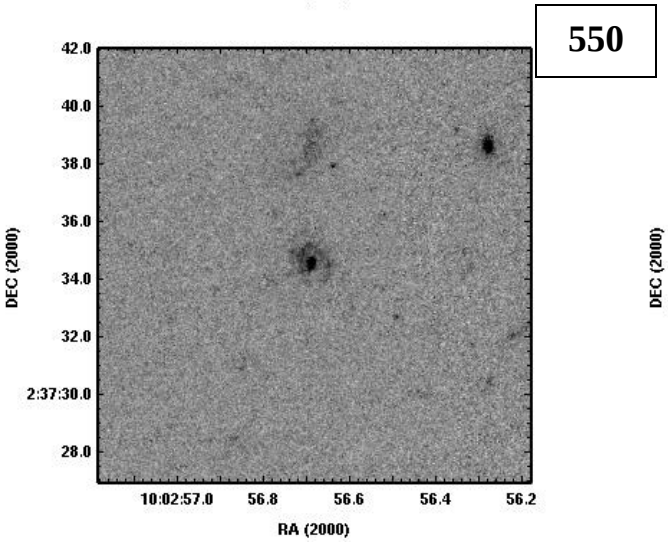
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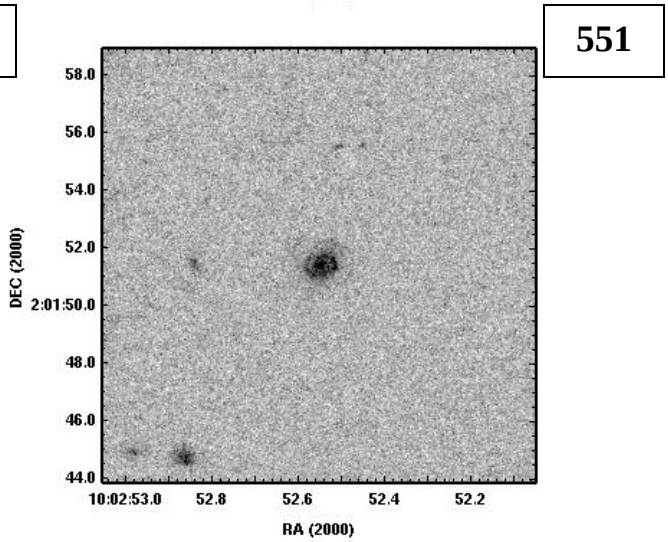
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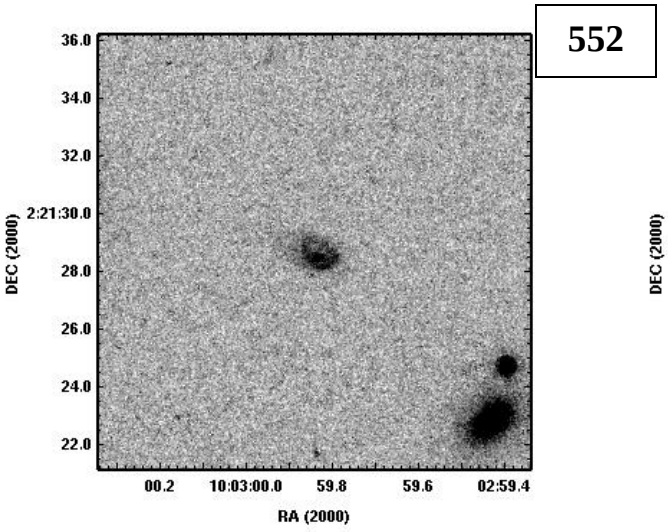
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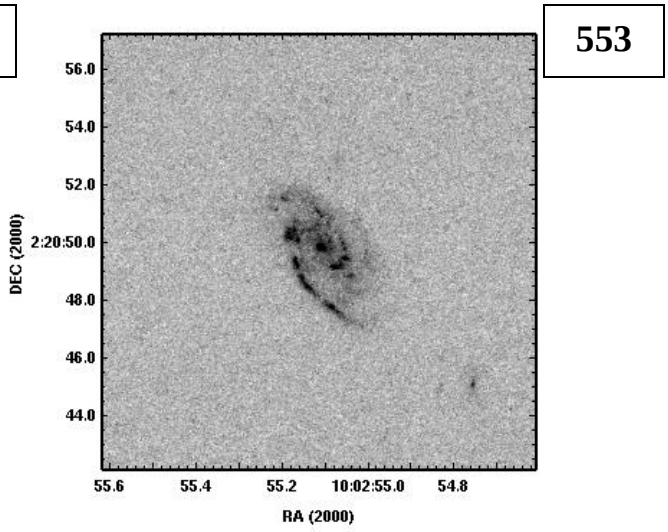
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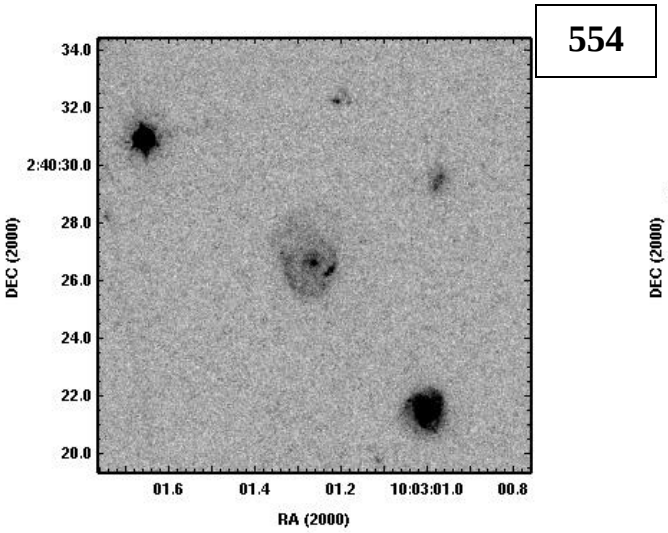
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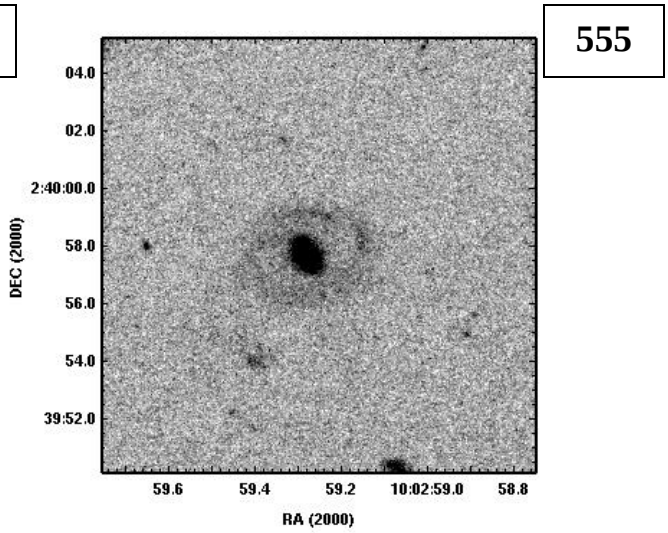
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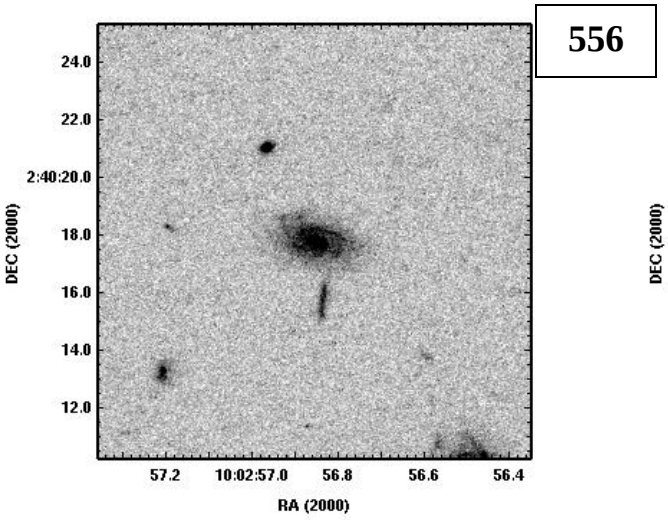
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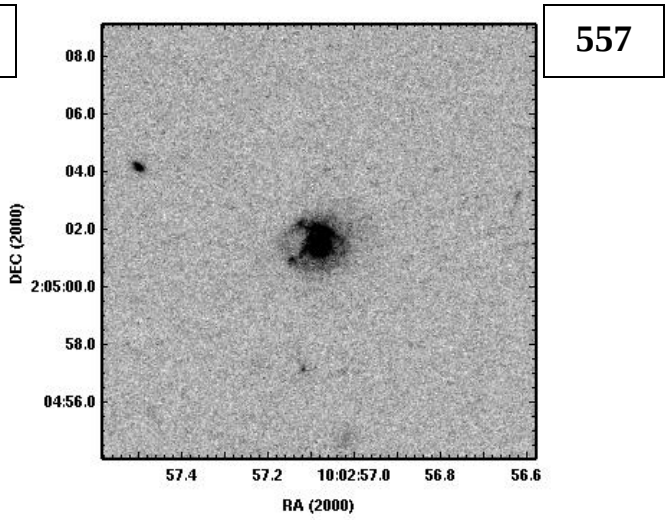
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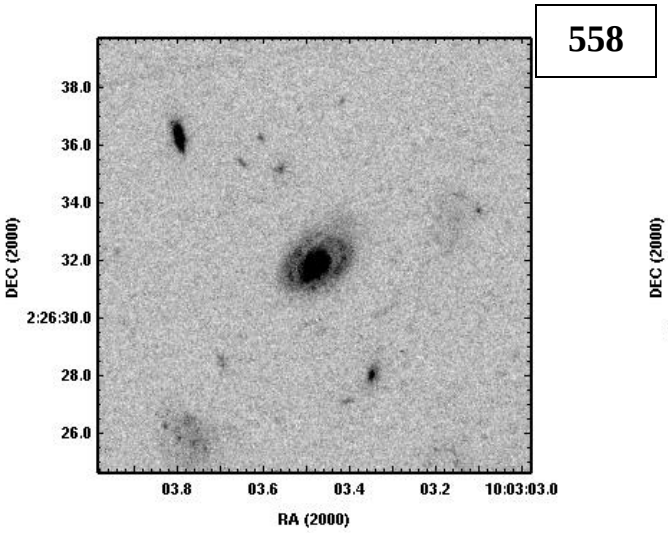
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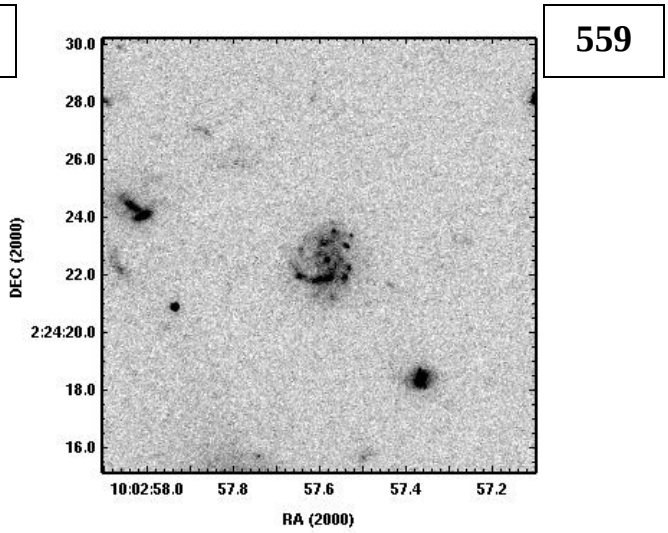
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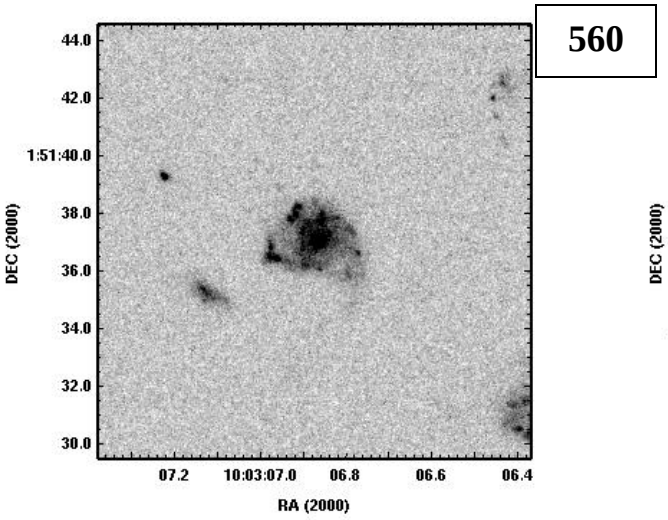
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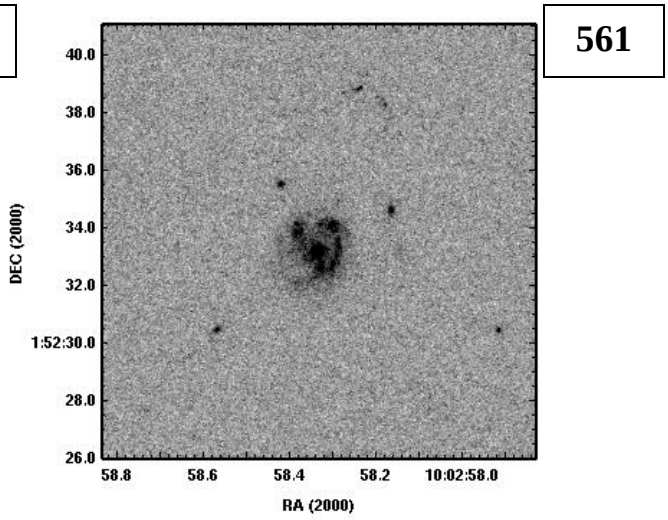
30.0
DEC (2000)
07.2
10:03:07.0
06.8
06.6
06.4
RA (2000)


561
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38.0
36.0
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32.0
1:52:30.0
28.0
26.0
DEC (2000)
58.8
58.6
58.4
58.2
10:02:58.0
RA (2000)

Table 4:

Ring ID	RA	DEC	e(B-V)	zphot	zphot error 95%min	zphot error 95%max	Abs *V*-Band Mag	logmass	f814w_mag|	f814w_ mag_err|
RING1	150.079	2.161	0.0191	0.31	0.24	0.42	-21.7	10.4	20.23	0.02
RING2	150.045	2.184	0.0195	0.19	0.06	0.27	-19.2	9.4	21.16	0.04
RING3	150.043	2.163	0.0194	0.36	0.27	0.41	-22.3	10.6	19.92	0.02
RING4	150.084	2.222	0.0190	0.56	0.46	0.67	-22.5	10.6	21.04	0.04
RING5	150.094	2.233	0.0186	0.37	0.27	0.42	-21.2	10.1	21.17	0.04
RING6	150.065	2.192	0.0194	0.38	0.26	0.5	-20.4	9.7	21.51	0.05
RING7	150.051	2.242	0.0193	0.27	0.16	0.32	-19.5	9.4	21.51	0.05
RING8	150.096	2.254	0.0183	0.32	0.25	0.39	-18.9	9.1	22.19	0.08
RING9	150.058	2.289	0.0185	0.7	0.65	0.93	-20.7	9.9	22.37	0.09
RING10	150.075	2.275	0.0185	0.33	0.27	0.4	-20.1	9.7	21.07	0.04
RING11	150.095	2.142	0.0187	0.6	0.55	0.73	-22.4	10.5	21.14	0.04
RING12	150.096	2.166	0.0189	0.69	0.59	0.74	-21.8	10.3	21.66	0.05
RING13	150.121	2.230	0.0181	0.74	0.65	0.82	-21.1	10.0	22.33	0.08
RING14	150.109	2.232	0.0183	0.87	0.72	1.15	-21.5	10.2	22.62	0.10
RING15	150.109	2.224	0.0185	0.37	0.29	0.42	-19.9	9.5	21.71	0.05
RING16	150.134	2.262	0.0174	0.77	0.67	0.87	-21.7	10.3	21.96	0.07
RING17	150.118	2.267	0.0176	0.84	0.77	0.9	-23.3	11.1	20.65	0.03
RING18	150.115	2.285	0.0175	0.47	0.36	0.54	-23.1	10.8	20.22	0.02
RING19	150.140	2.271	0.0171	0.43	0.33	0.52	-21.2	10.1	20.91	0.03
RING20	150.156	2.158	0.0174	0.7	0.67	0.73	-22.3	10.5	21.61	0.05
RING21	150.195	2.188	0.0168	0.69	0.57	0.75	-21.4	10.1	22.25	0.08
RING22	150.154	2.226	0.0174	0.38	0.34	0.48	-22.1	10.7	20.03	0.02
RING23	150.154	2.226	0.0174	0.38	0.34	0.48	-22.1	10.7	20.03	0.02
RING24	149.452	1.911	0.0199	1.02	0.92	1.08	-22.4	10.7	22.51	0.10
RING25	149.473	2.223	0.0194	0.96	0.8	1.35	-22.0	10.4	23.43	0.23
RING26	149.469	2.202	0.0192	0.72	0.65	0.9	-22.0	10.4	22.13	0.08
RING27	149.460	2.562	0.0201	1.47	1.12	1.6	-23.2	10.9	22.95	0.14
RING28	149.501	1.939	0.0195	0.92	0.77	1.07	-20.5	9.8	23.19	0.17
RING29	149.495	1.945	0.0195	1.06	0.89	1.17	-21.0	10.0	23.79	0.28
RING30	149.450	1.921	0.0200	0.7	0.63	1.06	-20.1	9.6	23.09	0.16
RING31	149.500	2.244	0.0193	1.53	1.35	1.84	-22.0	10.4	23.77	0.27
RING33	149.461	2.240	0.0199	1.23	1.05	1.38	-22.8	10.7	23.08	0.12
RING34	149.496	1.690	0.0199	0.69	0.55	0.74	-21.2	10.0	22.02	0.07
RING35	149.494	1.675	0.0197	0.75	0.67	0.85	-21.5	10.3	22.00	0.07
RING36	149.507	2.012	0.0195	0.95	0.84	1.06	-21.2	10.0	22.41	0.09
RING36	149.507	2.012	0.0195	0.98	0.86	1.16	-21.3	10.1	22.44	0.10
RING37	149.465	1.994	0.0199	0.94	0.77	1.11	-22.3	10.4	22.41	0.09
RING38	149.505	2.337	0.0205	1.35	0.74	1.58	-22.1	10.4	23.27	0.19
RING39	149.473	2.325	0.0209	0.24	0.21	0.25	-17.4	8.5	23.10	0.16
RING39	149.473	2.325	0.0209	0.24	0.23	0.25	-16.1	8.0	24.52	0.34
RING40	149.475	1.735	0.0210	0.8	0.63	1.05	-20.0	9.6	23.23	0.18
RING41	149.503	1.730	0.0207	1.04	0.91	1.14	-22.1	10.6	22.48	0.10
RING42	149.507	2.616	0.0192	0.73	0.58	0.89	-21.2	10.1	23.01	0.12
RING42	149.508	2.616	0.0192	0.46	0.34	0.58	-19.8	9.5	22.64	0.11
RING43	149.524	2.044	0.0196	0.94	0.85	1.08	-23.2	10.9	21.90	0.06

RING44	149.504	2.056	0.0195	0.99	0.74	1.08	-22.9	10.7	22.14	0.08
RING45	149.489	2.036	0.0195	0.78	0.7	0.99	-20.5	9.8	23.60	0.24
RING46	149.523	2.361	0.0202	1.15	0.95	1.36	-21.3	10.1	23.26	0.16
RING47	149.479	2.384	0.0207	1.15	0.82	1.49	-22.2	10.4	23.11	0.16
RING48	149.484	2.360	0.0206	1.04	0.96	1.18	-22.5	10.7	22.65	0.11
RING49	149.495	2.389	0.0205	0.99	0.86	1.14	-21.3	10.1	22.72	0.12
RING50	149.504	1.772	0.0209	0.64	0.54	0.68	-22.2	10.8	21.02	0.04
RING51	149.523	1.786	0.0206	0.96	0.73	1.53	-20.8	9.9	23.64	0.25
RING52	149.506	1.763	0.0209	0.94	0.73	1.12	-21.9	10.3	22.16	0.08
RING53	149.511	2.071	0.0196	0.66	0.53	0.71	-19.9	9.5	23.29	0.17
RING54	149.533	2.104	0.0195	0.99	0.79	1.16	-21.0	9.9	22.91	0.12
RING55	149.481	2.119	0.0191	0.84	0.74	1.09	-22.2	10.5	22.06	0.11
RING56	149.484	2.077	0.0194	1.5	0.77	1.62	-23.3	10.9	23.44	0.21
RING57	149.518	2.095	0.0195	0.8	0.73	1.25	-22.4	10.5	22.45	0.09
RING58	149.504	2.115	0.0192	0.89	0.73	1.06	-21.6	10.2	22.33	0.09
RING59	149.494	2.106	0.0192	0.81	0.64	1.01	-21.5	10.1	22.96	0.15
RING60	149.503	2.116	0.0192	1.23	1.12	1.39	-23.5	11.0	22.88	0.14
RING61	149.485	2.084	0.0193	0.71	0.55	0.84	-21.1	10.3	22.14	0.07
RING62	149.497	1.833	0.0201	0.99	0.92	1.05	-22.9	10.7	22.27	0.08
RING63	149.494	2.400	0.0205	0.7	0.6	0.89	-21.2	10.0	22.47	0.10
RING64	149.524	2.403	0.0203	0.85	0.69	0.96	-22.9	10.7	21.88	0.06
RING65	149.523	2.420	0.0204	0.92	0.74	1.06	-21.7	10.2	22.76	0.12
RING66	149.500	2.406	0.0205	1.1	0.98	1.19	-22.3	10.5	22.50	0.10
RING67	149.515	2.724	0.0194	0.6	0.09	1.56	-21.3	10.1	-99.00	-99.00
RING68	149.529	2.745	0.0191	0.9	0.83	0.97	-22.0	10.6	22.34	0.09
RING69	149.538	2.747	0.0189	1.06	0.74	1.13	-22.6	10.6	22.88	0.12
RING70	149.493	2.740	0.0198	1.06	0.94	1.21	-23.4	10.9	22.25	0.08
RING71	149.504	2.745	0.0196	1.12	0.89	1.43	-21.6	10.2	23.02	0.15
RING72	149.531	2.134	0.0192	0.44	0.38	0.54	-20.3	9.7	21.90	0.06
RING73	149.538	2.151	0.0191	0.86	0.69	1.1	-20.0	9.5	23.38	0.20
RING74	149.487	2.140	0.0189	1.06	0.97	1.12	-23.5	11.1	21.94	0.07
RING75	149.497	2.135	0.0189	0.44	0.39	0.54	-19.7	9.4	22.21	0.08
RING77	149.509	2.493	0.0210	0.9	0.84	0.98	-22.2	10.6	21.93	0.07
RING78	149.503	2.462	0.0210	1	0.94	1.19	-23.4	10.9	21.95	0.06
RING79	149.536	2.804	0.0189	1.14	1.04	1.37	-23.2	10.8	22.54	0.10
RING80	149.501	2.800	0.0194	1.1	0.78	1.84	-22.1	10.4	24.02	0.35
RING81	149.495	2.784	0.0194	1.49	0.8	1.59	-23.4	11.1	22.91	0.14
RING82	149.534	2.797	0.0189	0.15	0	0.26	-18.2	8.9	21.67	0.05
RING83	149.513	1.868	0.0199	0.75	0.68	1.07	-21.5	10.2	22.38	0.09
RING84	149.501	1.896	0.0198	1.56	0.81	2.12	-22.2	10.5	23.96	0.26
RING85	149.502	1.863	0.0199	0.72	0.65	0.77	-21.7	10.4	21.72	0.06
RING86	149.539	2.183	0.0187	1.03	0.94	1.1	-23.8	11.1	21.77	0.06
RING87	149.503	2.204	0.0187	1.04	0.99	1.12	-23.2	11.0	22.20	0.08
RING88	149.533	2.193	0.0185	1.24	0.79	1.44	-22.2	10.5	23.21	0.18
RING89	149.512	1.608	0.0191	0.64	0.58	0.78	-20.0	9.6	22.94	0.14
RING90	149.508	2.508	0.0208	1.01	0.92	1.08	-22.0	10.5	22.08	0.07
RING91	149.529	1.932	0.0195	0.56	0.43	0.69	-20.3	9.7	22.68	0.13
RING92	149.530	1.909	0.0197	1.51	0.71	1.62	-22.9	10.7	23.74	0.27
RING93	149.555	1.952	0.0195	1.69	1.45	2.31	-22.5	10.5	23.93	0.33

RING94	149.542	1.951	0.0194	1.17	1	1.32	-22.4	10.5	22.89	0.14
RING95	149.526	2.850	0.0194	1.14	0.97	1.46	-21.9	10.3	22.91	0.14
RING96	149.507	2.831	0.0194	0.75	0.7	0.84	-22.8	11.0	20.98	0.03
RING97	149.529	2.844	0.0192	0.7	0.62	1.04	-20.7	9.8	22.96	0.16
RING98	149.518	2.862	0.0197	1.21	1.03	1.35	-22.6	10.6	23.45	0.22
RING99	149.548	1.640	0.0191	1.2	1.04	1.36	-22.9	10.9	22.53	0.10
RING100	149.514	1.637	0.0191	1.65	1.52	1.83	-23.9	11.3	22.72	0.09
RING101	149.513	2.274	0.0198	0.64	0.6	0.81	-20.4	9.7	22.51	0.10
RING102	149.536	2.581	0.0192	0.66	0.53	0.73	-21.7	10.3	22.01	0.07
RING103	149.561	2.007	0.0196	0.87	0.79	0.96	-22.5	10.7	22.26	0.08
RING104	149.551	1.989	0.0194	0.88	0.71	1.12	-22.0	10.3	23.04	0.15
RING105	149.525	2.320	0.0202	0.75	0.6	0.89	-20.8	9.9	22.73	0.12
RING106	149.521	1.701	0.0198	0.95	0.8	1.55	-20.4	9.7	23.66	0.25
RING107	149.575	2.059	0.0196	0.83	0.66	1.01	-21.4	10.2	22.33	0.07
RING108	149.524	2.044	0.0196	0.94	0.85	1.08	-23.2	10.9	21.90	0.06
RING109	149.551	1.753	0.0203	0.56	0.47	0.66	-19.5	9.4	23.33	0.22
RING110	149.571	2.113	0.0197	0.69	0.53	0.76	-20.8	9.9	22.24	0.07
RING111	149.542	2.103	0.0196	0.66	0.57	0.7	-23.0	11.1	20.75	0.03
RING112	149.533	2.104	0.0195	0.99	0.79	1.16	-21.0	9.9	22.91	0.12
RING113	149.543	2.073	0.0197	1.18	1.1	1.2	-23.0	10.8	22.76	0.12
RING114	149.549	2.688	0.0184	1.02	0.75	1.14	-21.8	10.3	22.90	0.13
RING115	149.565	2.403	0.0203	0.86	0.71	0.94	-22.2	10.5	22.32	0.09
RING116	149.561	2.761	0.0185	1.02	0.81	1.16	-22.3	10.5	22.48	0.10
RING117	149.558	2.731	0.0185	0.56	0.42	0.66	-20.5	9.7	22.15	0.08
RING118	149.572	2.147	0.0195	0.6	0.54	0.71	-22.4	10.5	21.45	0.05
RING119	149.576	2.465	0.0205	1.08	1	1.22	-23.3	10.9	22.15	0.08
RING120	149.551	1.884	0.0198	1.22	1.05	1.44	-23.9	11.1	22.13	0.07
RING121	149.600	2.793	0.0185	0.97	0.81	1.12	-23.3	10.8	21.97	0.06
RING122	149.580	2.193	0.0190	0.85	0.69	0.96	-22.0	10.4	21.90	0.06
RING123	149.588	2.183	0.0192	0.99	0.75	1.16	-21.6	10.2	22.50	0.10
RING124	149.567	2.543	0.0198	1	0.89	1.08	-22.0	10.5	22.57	0.11
RING125	149.585	1.615	0.0198	0.86	0.67	0.95	-22.1	10.4	22.12	0.08
RING126	149.559	1.925	0.0196	0.72	0.64	1.09	-20.8	9.9	22.50	0.10
RING127	149.558	2.837	0.0188	0.39	0.27	0.44	-19.6	9.4	22.45	0.10
RING128	149.602	2.232	0.0189	0.96	0.8	1.06	-22.0	10.4	22.65	0.11
RING129	149.612	1.948	0.0195	0.53	0.38	0.59	-19.8	9.5	22.72	0.11
RING130	149.584	2.570	0.0193	1.24	1.12	1.38	-23.2	11.0	22.44	0.10
RING131	149.566	2.556	0.0196	0.81	0.67	0.91	-22.6	10.6	21.91	0.06
RING132	149.586	2.558	0.0195	1.03	0.98	1.16	-24.0	11.2	21.55	0.05
RING133	149.583	2.324	0.0198	0.74	0.69	0.95	-22.4	10.5	21.61	0.05
RING134	149.607	1.694	0.0195	0.82	0.73	0.88	-23.0	10.9	20.93	0.03
RING135	149.604	1.721	0.0197	0.75	0.7	0.8	-23.0	11.0	21.04	0.04
RING136	149.614	2.337	0.0200	0.85	0.69	0.92	-21.6	10.3	22.34	0.09
RING137	149.627	1.767	0.0199	0.77	0.7	0.84	-21.4	10.3	22.29	0.08
RING138	149.584	2.683	0.0180	0.88	0.72	0.99	-22.0	10.4	22.23	0.08
RING139	149.603	2.069	0.0195	0.96	0.74	1.16	-21.7	10.2	22.51	0.10
RING140	149.606	2.387	0.0204	0.12	0.05	0.18	-21.0	10.3	-99.00	-99.00
RING141	149.634	2.391	0.0205	0.93	0.75	1.03	-22.4	10.7	21.87	0.06
RING142	149.634	2.390	0.0205	0.92	0.83	1.01	-22.3	10.7	22.00	0.07

RING143	149.630	2.697	0.0186	1.18	0.99	1.36	-22.5	10.6	22.77	0.10
RING144	149.634	1.810	0.0200	1.54	1.38	1.64	-23.5	11.1	22.96	0.14
RING145	149.618	2.141	0.0195	0.3	0.29	0.36	-19.7	9.4	21.58	0.05
RING146	149.643	2.471	0.0203	0.5	0.43	0.64	-23.4	11.1	20.25	0.02
RING147	149.639	2.800	0.0186	1.19	0.99	1.2	-23.4	10.9	22.05	0.07
RING148	149.645	1.873	0.0200	0.17	0	0.25	-19.1	9.2	20.94	0.03
RING149	149.626	1.886	0.0198	0.8	0.68	0.91	-21.7	10.4	22.10	0.07
RING150	149.614	1.835	0.0198	1.07	0.92	1.21	-22.3	10.5	22.52	0.08
RING151	149.654	2.173	0.0194	0.58	0.52	0.71	-22.3	10.5	21.46	0.04
RING152	149.627	2.197	0.0193	1.16	1.08	1.24	-22.8	10.7	22.98	0.14
RING153	149.654	2.834	0.0191	0.84	0.7	1.06	-21.9	10.4	22.12	0.07
RING154	149.652	2.253	0.0195	1.09	1	1.14	-23.1	10.9	22.10	0.07
RING155	149.673	2.583	0.0194	0.73	0.61	0.85	-24.0	11.1	20.42	0.02
RING156	149.631	2.570	0.0195	0.52	0.42	0.59	-22.3	10.5	20.79	0.03
RING157	149.669	1.968	0.0193	0.92	0.71	1.08	-22.2	10.4	22.41	0.09
RING158	149.647	2.311	0.0199	0.83	0.76	0.88	-22.4	10.6	21.62	0.05
RING159	149.673	2.583	0.0194	0.73	0.61	0.85	-24.0	11.1	20.42	0.02
RING160	149.638	2.369	0.0204	0.38	0.31	0.49	-22.9	10.9	19.75	0.02
RING161	149.678	2.392	0.0207	0.6	0.52	0.71	-20.6	9.8	22.37	0.09
RING162	149.660	2.411	0.0207	0.74	0.71	1.21	-22.5	10.5	21.64	0.05
RING163	149.663	1.813	0.0203	0.71	0.67	0.8	-22.8	10.8	21.03	0.04
RING164	149.671	1.868	0.0203	0.99	0.81	1.08	-23.1	10.9	21.68	0.05
RING165	149.683	2.784	0.0189	1.01	0.94	1.11	-23.3	10.9	22.24	0.08
RING166	149.664	1.911	0.0198	0.87	0.71	1.07	-23.0	10.8	21.92	0.06
RING167	149.686	1.920	0.0197	1.14	1.06	1.3	-23.4	10.9	22.11	0.07
RING168	149.689	2.497	0.0194	0.62	0.47	0.64	-23.2	11.2	20.24	0.02
RING169	149.693	2.805	0.0191	0.69	0.57	0.73	-21.4	10.1	21.82	0.06
RING170	149.692	2.205	0.0197	0.59	0.49	0.68	-22.3	10.5	21.16	0.04
RING171	149.687	2.209	0.0197	1.06	0.74	1.16	-23.2	10.8	22.05	0.08
RING172	149.674	1.646	0.0209	0.49	0.39	0.6	-22.4	10.7	20.45	0.03
RING173	149.722	1.689	0.0210	0.58	0.5	0.65	-22.5	10.7	20.78	0.03
RING174	149.719	2.264	0.0205	0.2	0.07	0.28	-21.6	10.2	19.67	0.02
RING175	149.679	2.300	0.0203	0.7	0.56	0.79	-20.7	9.9	22.82	0.12
RING176	149.673	2.583	0.0194	0.73	0.61	0.85	-24.0	11.1	20.42	0.02
RING177	149.721	2.605	0.0191	0.61	0.54	0.7	-23.1	10.8	20.42	0.02
RING178	149.726	2.013	0.0193	0.93	0.85	1	-22.8	10.7	22.30	0.08
RING179	149.728	2.316	0.0211	0.51	0.44	0.54	-21.9	10.5	20.96	0.03
RING180	149.708	2.339	0.0211	0.99	0.92	1.04	-22.9	10.9	21.90	0.06
RING181	149.700	2.388	0.0209	1.17	0.96	1.5	-22.6	10.6	22.82	0.13
RING182	149.693	1.768	0.0205	0.7	0.62	0.8	-21.8	10.4	21.51	0.04
RING183	149.706	2.460	0.0197	1	0.78	1.08	-23.2	10.9	21.71	0.05
RING184	149.730	2.421	0.0204	0.84	0.71	1.05	-21.7	10.3	22.09	0.07
RING185	149.741	1.859	0.0207	0.3	0.27	0.41	-19.7	9.5	21.58	0.05
RING186	149.718	1.825	0.0209	0.94	0.87	1.02	-23.3	11.1	21.43	0.05
RING187	149.757	2.764	0.0203	0.61	0.53	0.71	-22.2	10.4	21.84	0.06
RING188	149.745	2.466	0.0193	0.34	0.27	0.4	-19.9	9.5	21.61	0.05
RING189	149.774	1.969	0.0189	0.79	0.64	0.86	-22.9	10.7	21.41	0.05
RING190	149.754	2.246	0.0201	0.78	0.68	0.85	-22.3	10.6	21.48	0.05
RING191	149.724	2.268	0.0205	1.01	0.89	1.11	-23.1	10.8	22.11	0.06

RING192	149.758	2.012	0.0192	0.76	0.62	0.86	-21.2	10.0	22.20	0.08
RING193	149.776	1.714	0.0217	1.91	1.46	2.47	-23.4	10.9	24.13	0.27
RING193	149.776	1.714	0.0217	1.96	1.44	2.27	-23.0	10.8	23.78	0.23
RING194	149.751	1.743	0.0213	0.96	0.77	1.75	-21.1	10.0	23.03	0.15
RING195	149.785	2.375	0.0206	1.24	1.04	1.44	-21.8	10.3	23.17	0.17
RING196	149.791	2.691	0.0199	0.48	0.42	0.55	-22.9	10.7	20.39	0.02
RING197	149.785	2.438	0.0196	0.23	0.12	0.29	-19.4	9.3	21.30	0.04
RING198	149.763	2.422	0.0201	0.85	0.65	1.03	-21.9	10.3	22.53	0.10
RING199	149.805	1.833	0.0206	1.66	1.43	2.16	-24.5	11.3	23.29	0.18
RING200	149.783	1.837	0.0206	1.1	0.77	1.61	-21.6	10.2	23.03	0.16
RING201	149.774	2.756	0.0204	0.92	0.77	1.12	-21.7	10.2	22.56	0.10
RING202	149.759	2.771	0.0203	0.68	0.6	0.81	-20.9	9.9	22.73	0.10
RING203	149.801	2.131	0.0207	0.75	0.72	1.17	-21.5	10.1	22.57	0.10
RING204	149.805	1.875	0.0204	1.38	1.25	1.53	-23.8	11.1	23.24	0.18
RING205	149.809	2.185	0.0200	0.88	0.72	1.11	-21.3	10.1	22.90	0.13
RING206	149.771	2.527	0.0179	1.29	0.75	2.09	-22.0	10.4	23.56	0.21
RING207	149.791	2.542	0.0179	0.52	0.42	0.58	-21.7	10.3	21.05	0.04
RING208	149.791	1.947	0.0189	0.96	0.84	1.04	-22.2	10.5	22.89	0.14
RING209	149.829	2.869	0.0217	1.14	0.97	1.4	-22.2	10.5	22.99	0.14
RING210	149.831	1.668	0.0213	1.34	1.06	1.45	-23.0	10.9	22.84	0.13
RING211	149.836	2.336	0.0198	1.02	0.76	1.11	-22.5	10.6	22.10	0.07
RING211	149.836	2.335	0.0198	1.02	0.75	1.16	-22.3	10.5	22.58	0.10
RING212	149.793	2.301	0.0203	0.7	0.6	0.81	-23.0	10.8	21.06	0.04
RING213	149.805	2.644	0.0192	1.21	1.05	1.47	-22.9	10.7	23.14	0.17
RING214	149.817	2.028	0.0197	0.47	0.4	0.56	-22.4	10.7	20.31	0.02
RING215	149.814	2.386	0.0200	0.92	0.77	1.6	-20.8	9.9	23.33	0.19
RING216	149.815	2.671	0.0193	1.51	1.23	1.82	-22.7	10.6	23.22	0.17
RING217	149.853	2.100	0.0214	0.6	0.59	0.79	-21.6	10.2	22.22	0.08
RING218	149.854	2.421	0.0194	1.01	0.68	1.09	-23.1	10.8	21.94	0.06
RING219	149.859	2.163	0.0207	0.97	0.85	1.04	-22.8	10.7	22.47	0.10
RING220	149.816	2.175	0.0201	0.74	0.61	0.83	-20.9	9.9	22.26	0.07
RING221	149.819	2.172	0.0202	1.12	0.84	1.55	-21.7	10.3	23.08	0.15
RING222	149.861	2.222	0.0200	0.94	0.73	1.13	-21.6	10.2	22.60	0.11
RING223	149.834	2.202	0.0199	0.8	0.68	1.06	-20.9	9.9	22.46	0.10
RING224	149.832	1.616	0.0216	0.84	0.75	0.93	-22.5	10.6	22.13	0.08
RING225	149.874	1.917	0.0199	0.81	0.73	0.87	-21.8	10.4	21.95	0.06
RING226	149.846	2.508	0.0190	0.83	0.74	0.9	-22.5	10.7	21.65	0.05
RING227	149.851	1.655	0.0204	0.64	0.59	0.79	-23.1	10.8	21.44	0.05
RING228	149.857	2.293	0.0198	0.34	0.29	0.46	-21.7	10.6	20.08	0.02
RING229	149.861	2.608	0.0186	0.98	0.92	1.19	-23.0	10.8	22.51	0.10
RING230	149.879	2.601	0.0189	0.96	0.77	1.06	-22.5	10.6	22.61	0.10
RING230	149.878	2.602	0.0189	0.98	0.77	1.14	-21.6	10.2	22.92	0.12
RING231	149.871	1.795	0.0211	0.92	0.71	1.08	-21.4	10.1	23.04	0.15
RING232	149.908	2.757	0.0205	1.04	0.97	1.15	-22.2	10.6	22.65	0.09
RING233	149.901	1.885	0.0204	0.68	0.59	0.71	-21.6	10.2	21.96	0.07
RING234	149.908	2.757	0.0205	1.04	0.97	1.15	-22.2	10.6	22.65	0.09
RING235	149.904	2.177	0.0205	1.05	0.92	1.11	-23.5	11.1	21.78	0.06
RING236	149.932	1.933	0.0193	0.88	0.72	1.12	-21.7	10.2	22.12	0.07
RING237	149.883	2.813	0.0214	0.79	0.68	1.01	-21.4	10.1	22.18	0.06

RING238	149.935	2.550	0.0189	0.83	0.7	1.08	-21.6	10.2	22.01	0.06
RING239	149.934	2.550	0.0189	0.49	0.41	0.55	-22.3	10.7	20.29	0.02
RING240	149.900	1.632	0.0190	1.58	1.42	2.07	-23.8	11.1	22.72	0.12
RING241	149.937	2.697	0.0204	1	0.79	1.08	-23.0	10.8	21.77	0.05
RING242	149.918	2.692	0.0201	1.53	1.38	1.93	-23.9	11.1	23.08	0.16
RING243	149.953	2.396	0.0180	1.5	0.71	1.9	-22.3	10.5	24.42	0.18
RING243	149.953	2.396	0.0180	0.72	0.7	1.95	-19.9	9.5	23.28	0.11
RING244	149.915	1.790	0.0214	0.78	0.68	0.86	-23.2	10.9	21.22	0.04
RING245	149.949	2.740	0.0208	0.78	0.73	1.4	-20.9	9.9	23.00	0.15
RING246	149.967	1.849	0.0206	0.89	0.8	0.93	-23.5	11.1	20.85	0.03
RING247	149.950	2.798	0.0210	0.35	0.25	0.42	-21.3	10.4	20.20	0.02
RING248	149.972	1.638	0.0183	0.96	0.76	1.79	-20.4	9.7	23.56	0.24
RING249	149.974	1.644	0.0183	1.16	1.06	1.32	-24.9	11.5	21.28	0.04
RING250	149.943	2.540	0.0187	1.26	1.21	1.56	-22.4	10.5	22.64	0.11
RING251	149.977	1.668	0.0182	1.15	1.07	1.28	-22.8	10.8	22.59	0.11
RING252	149.950	1.683	0.0183	0.8	0.73	0.92	-21.6	10.4	22.63	0.11
RING253	149.987	1.718	0.0184	0.68	0.6	0.71	-23.2	11.2	20.29	0.02
RING254	149.981	1.759	0.0198	0.56	0.4	0.69	-19.5	9.3	22.93	0.14
RING255	149.978	2.094	0.0198	0.84	0.71	1.07	-22.3	10.5	22.32	0.07
RING256	150.012	2.714	0.0211	1	0.83	1.06	-21.5	10.2	22.83	0.11
RING257	150.015	2.436	0.0173	1.01	0.86	1.78	-21.0	10.0	23.02	0.15
RING258	150.002	1.844	0.0197	1.21	1.08	1.44	-23.9	11.1	22.69	0.13
RING259	150.030	1.878	0.0183	0.84	0.69	0.91	-22.3	10.5	21.88	0.06
RING260	150.021	2.228	0.0196	0.69	0.59	0.77	-21.3	10.1	22.02	0.07
RING261	150.030	1.625	0.0187	0.81	0.68	0.91	-21.2	10.1	22.31	0.09
RING262	150.014	1.967	0.0187	1.03	0.87	1.18	-22.8	10.7	22.84	0.13
RING263	150.005	1.686	0.0180	0.81	0.73	1.52	-22.1	10.4	22.91	0.14
RING264	150.043	2.603	0.0188	0.83	0.78	0.86	-23.1	11.1	21.24	0.04
RING265	150.064	1.756	0.0171	0.8	0.69	1.03	-22.8	10.7	21.97	0.06
RING266	150.056	2.449	0.0174	0.85	0.8	0.89	-23.4	11.3	20.98	0.04
RING267	150.046	2.428	0.0174	0.83	0.72	0.9	-21.9	10.5	22.08	0.07
RING268	150.078	1.839	0.0173	1.13	0.78	1.49	-22.0	10.4	22.86	0.13
RING269	150.064	2.157	0.0192	0.96	0.9	1.08	-23.2	10.9	21.87	0.06
RING270	150.079	2.186	0.0193	0.93	0.84	1.01	-22.3	10.6	22.03	0.06
RING271	150.090	1.889	0.0174	1.02	0.93	1.12	-23.5	11.0	21.97	0.06
RING272	150.077	1.891	0.0176	1.24	1.16	1.4	-23.4	11.1	22.74	0.12
RING273	150.086	1.910	0.0176	0.93	0.81	1.02	-22.8	10.7	21.71	0.06
RING274	150.068	1.897	0.0177	0.69	0.57	0.83	-21.9	10.3	22.00	0.07
RING275	150.087	2.825	0.0191	1.2	1.01	1.21	-23.0	10.8	22.65	0.11
RING276	150.045	1.613	0.0188	1.51	0.72	1.87	-22.6	10.7	23.41	0.21
RING277	150.059	1.606	0.0188	1.05	0.97	1.19	-23.0	10.8	22.36	0.09
RING278	150.095	2.214	0.0189	0.73	0.65	0.83	-22.4	10.6	21.30	0.04
RING279	150.059	2.220	0.0194	1.08	1.03	1.28	-23.8	11.1	21.88	0.06
RING280	150.081	2.548	0.0179	0.01	0	2.37	-9.4	-99.0	23.88	0.25
RING280	150.081	2.548	0.0179	2.32	0	2.47	-23.0	10.8	23.45	0.21
RING281	150.099	2.873	0.0191	0.73	0.65	0.84	-21.5	10.3	22.07	0.07
RING282	150.060	2.842	0.0194	0.83	0.74	0.9	-22.9	10.9	21.39	0.04
RING283	150.063	2.592	0.0187	0.69	0.58	0.79	-22.2	10.5	21.65	0.05
RING284	150.101	2.003	0.0185	0.84	0.77	0.88	-23.8	11.4	20.68	0.03

RING285	150.109	2.016	0.0184	0.85	0.72	0.93	-21.5	10.2	22.35	0.09
RING286	150.093	2.321	0.0176	0.39	0.28	0.45	-20.5	9.8	21.78	0.06
RING287	150.074	1.749	0.0169	0.66	0.59	0.75	-23.6	11.0	20.61	0.03
RING288	150.094	2.633	0.0191	1.39	1.08	1.51	-24.0	11.2	22.74	0.12
RING289	150.077	2.395	0.0174	1.04	0.83	1.09	-23.0	10.9	21.84	0.06
RING290	150.064	1.756	0.0171	0.8	0.69	1.03	-22.8	10.7	21.97	0.06
RING291	150.127	2.708	0.0195	0.84	0.74	0.89	-22.9	11.1	21.28	0.04
RING292	150.124	2.424	0.0174	0.2	0.14	0.28	-21.6	10.5	-99.00	-99.00
RING293	150.090	2.774	0.0198	1.27	1.08	1.41	-24.3	11.3	22.29	0.08
RING294	150.139	2.523	0.0174	0.09	0.04	0.16	-19.7	9.8	-99.00	-99.00
RING295	150.129	1.923	0.0177	1.05	0.98	1.13	-22.3	10.7	22.47	0.10
RING296	150.104	1.950	0.0181	1.54	0.9	1.77	-23.0	10.9	23.28	0.19
RING297	150.118	2.267	0.0176	0.84	0.77	0.9	-23.3	11.1	20.65	0.03
RING298	150.138	1.685	0.0183	0.21	0.01	0.3	-17.8	8.7	22.40	0.09
RING299	150.127	2.708	0.0195	0.84	0.74	0.89	-22.9	11.1	21.28	0.04
RING300	150.165	1.760	0.0178	0.54	0.41	0.6	-20.8	9.9	21.76	0.06
RING301	150.166	1.807	0.0177	0.98	0.92	1.03	-23.4	11.1	21.84	0.06
RING302	150.154	1.804	0.0176	1.2	1.11	1.3	-23.4	11.0	22.40	0.10
RING303	150.135	2.743	0.0189	1.32	1.14	1.39	-23.7	11.2	22.50	0.10
RING304	150.147	2.797	0.0183	1.1	0.74	1.71	-22.7	10.6	22.29	0.09
RING305	150.179	1.622	0.0197	1.22	1.01	1.41	-23.4	10.9	22.60	0.12
RING305	150.179	1.622	0.0197	1.06	1.01	1.41	-21.2	10.0	23.49	0.19
RING306	150.148	2.198	0.0178	0.95	0.86	1.03	-22.9	10.9	21.96	0.06
RING307	150.179	2.509	0.0179	0.82	0.67	0.9	-22.7	10.7	21.38	0.04
RING308	150.160	1.922	0.0176	0.99	0.88	1.07	-22.7	10.8	22.00	0.07
RING309	150.169	2.843	0.0186	0.74	0.66	0.8	-23.3	11.2	20.67	0.03
RING310	150.163	1.646	0.0193	1.02	0.92	1.08	-23.2	10.9	22.09	0.07
RING310	150.162	1.646	0.0193	0.91	0.67	1.01	-20.0	9.5	23.92	0.14
RING311	150.208	2.590	0.0176	0.32	0.25	0.38	-21.7	10.4	20.17	0.02
RING312	150.190	1.707	0.0188	0.78	0.67	0.87	-23.1	10.8	21.06	0.04
RING313	150.183	2.054	0.0173	0.9	0.83	0.95	-22.5	10.7	21.76	0.06
RING314	150.208	2.094	0.0166	0.85	0.74	0.92	-22.4	10.5	21.96	0.07
RING315	150.195	1.842	0.0179	0.85	0.74	1.02	-22.3	10.5	22.16	0.06
RING316	150.214	2.733	0.0185	0.39	0.27	0.46	-21.7	10.4	20.34	0.02
RING317	150.192	2.446	0.0183	0.65	0.53	0.72	-21.7	10.4	21.61	0.05
RING318	150.216	2.173	0.0165	0.76	0.65	0.81	-22.6	10.9	21.24	0.04
RING319	150.228	2.243	0.0168	0.41	0.31	0.51	-21.8	10.4	20.79	0.03
RING320	150.240	2.822	0.0190	0.97	0.86	1.04	-22.7	10.8	21.97	0.07
RING321	150.256	2.835	0.0192	0.97	0.88	1.04	-23.3	11.1	21.40	0.04
RING322	150.264	1.971	0.0183	1.04	0.91	1.17	-23.9	11.1	21.58	0.05
RING323	150.254	2.316	0.0178	0.66	0.59	0.71	-21.1	10.0	22.17	0.08
RING324	150.238	2.410	0.0182	0.96	0.83	1.06	-22.5	10.6	22.62	0.10
RING325	150.271	2.141	0.0158	0.89	0.84	0.97	-23.2	11.0	21.47	0.05
RING326	150.263	2.522	0.0200	0.84	0.78	0.9	-22.3	10.6	21.72	0.06
RING327	150.256	2.835	0.0192	0.97	0.88	1.04	-23.3	11.1	21.40	0.04
RING328	150.305	2.843	0.0199	0.67	0.52	0.74	-22.1	10.8	21.33	0.04
RING329	150.312	1.657	0.0203	0.79	0.72	0.86	-23.3	11.0	20.96	0.03
RING330	150.264	2.542	0.0198	0.69	0.64	0.8	-23.5	11.0	20.48	0.03
RING331	150.313	2.299	0.0174	0.79	0.72	0.85	-23.3	11.2	20.92	0.03

RING332	150.308	1.667	0.0201	1.68	1.64	1.74	-24.6	11.4	20.92	0.03
RING333	150.286	2.617	0.0191	0.8	0.68	0.88	-22.4	10.5	22.05	0.07
RING334	150.313	2.091	0.0163	0.8	0.69	0.87	-23.1	10.8	21.49	0.04
RING335	150.352	1.856	0.0191	0.98	0.86	1.04	-22.1	10.7	22.44	0.09
RING336	150.350	2.763	0.0195	0.96	0.77	1	-23.3	11.2	21.45	0.05
RING337	150.310	1.895	0.0192	1.25	1.08	1.59	-23.4	10.9	22.39	0.09
RING338	150.352	2.219	0.0161	0.63	0.51	0.67	-23.2	11.2	20.25	0.02
RING339	150.372	2.563	0.0206	0.36	0.28	0.44	-21.5	10.5	20.20	0.02
RING340	150.345	1.699	0.0190	0.28	0.17	0.35	-21.8	10.6	19.56	0.02
RING341	150.366	1.992	0.0185	2.02	1.82	2.15	-26.3	12.1	22.51	0.10
RING342	150.372	1.715	0.0186	0.48	0.36	0.53	-23.2	10.9	20.04	0.02
RING343	150.343	1.730	0.0185	0.86	0.68	0.92	-23.0	10.8	21.44	0.05
RING344	150.344	1.773	0.0184	0.96	0.75	1.1	-23.9	11.1	21.89	0.06
RING345	150.377	2.460	0.0203	1.29	1.23	1.4	-24.5	11.4	22.13	0.07
RING346	150.406	1.943	0.0182	0.97	0.84	1.08	-22.6	10.6	22.48	0.10
RING347	150.388	1.963	0.0186	1.02	0.91	1.12	-22.4	10.7	22.16	0.07
RING348	150.422	2.210	0.0167	1.25	1.06	1.39	-22.9	10.8	22.34	0.08
RING349	150.388	2.864	0.0207	0.79	0.72	0.85	-22.4	10.7	21.64	0.05
RING350	150.414	2.015	0.0182	0.69	0.58	0.98	-20.9	9.9	22.23	0.08
RING351	150.417	1.999	0.0182	0.48	0.36	0.54	-20.9	9.9	21.47	0.05
RING352	150.393	1.978	0.0185	0.92	0.73	1.08	-22.5	10.5	22.52	0.10
RING353	150.416	2.632	0.0202	1.36	1.05	1.46	-22.8	10.8	22.94	0.14
RING354	150.399	2.627	0.0199	0.08	0	0.19	-17.7	8.7	21.15	0.04
RING355	150.395	2.639	0.0198	1.09	0.98	1.18	-24.0	11.2	22.13	0.07
RING356	150.399	2.024	0.0181	0.72	0.58	0.77	-21.4	10.1	22.11	0.07
RING357	150.433	2.063	0.0180	0.16	0.1	0.21	-21.0	10.3	-99.00	-99.00
RING358	150.421	2.352	0.0181	0.31	0.24	0.39	-20.4	9.7	21.10	0.04
RING359	150.426	2.090	0.0176	1.55	1.36	1.68	-23.1	10.9	23.12	0.16
RING360	150.424	2.117	0.0171	0.29	0.22	0.4	-21.1	10.0	20.28	0.02
RING361	150.418	2.074	0.0177	1.29	1.04	1.42	-23.6	11.0	22.73	0.13
RING362	150.437	2.697	0.0203	1	0.74	1.12	-21.7	10.3	23.07	0.16
RING363	150.432	2.683	0.0203	1.34	1.25	1.4	-24.6	11.6	21.98	0.07
RING364	150.427	2.719	0.0200	1.23	0.78	1.52	-22.3	10.5	23.79	0.13
RING364	150.426	2.719	0.0200	0.76	0.73	1.36	-21.4	10.1	22.06	0.06
RING365	150.412	2.716	0.0199	1.01	0.87	1.11	-22.4	10.7	22.21	0.08
RING366	150.454	2.442	0.0192	0.08	0	0.14	-19.0	9.3	20.44	0.02
RING367	150.437	1.804	0.0190	0.98	0.89	1.04	-23.2	11.0	21.74	0.06
RING368	150.446	1.805	0.0190	1.23	0.83	1.4	-23.1	10.8	23.01	0.14
RING369	150.423	1.807	0.0190	0.81	0.7	0.85	-23.8	11.1	20.87	0.03
RING370	150.414	1.848	0.0188	0.98	0.87	1.16	-24.5	11.4	20.81	0.03
RING371	150.449	2.725	0.0201	0.48	0.39	0.57	-21.8	10.5	21.05	0.04
RING372	150.439	2.766	0.0200	0.82	0.67	0.95	-22.7	10.6	21.90	0.06
RING373	150.445	2.755	0.0200	0.38	0.26	0.44	-19.8	9.5	21.93	0.07
RING374	150.427	2.719	0.0200	1.23	0.78	1.52	-22.3	10.5	23.79	0.13
RING374	150.426	2.719	0.0200	0.76	0.73	1.36	-21.4	10.1	22.06	0.06
RING375	150.411	2.721	0.0199	1.15	0.82	1.52	-22.2	10.4	22.72	0.09
RING376	150.407	2.735	0.0199	1.01	0.93	1.08	-23.3	11.0	21.84	0.06
RING377	150.445	2.134	0.0169	0.53	0.41	0.68	-19.4	9.3	23.19	0.17
RING378	150.407	2.464	0.0201	0.86	0.79	1.08	-20.6	9.8	23.01	0.13

RING379	150.464	1.883	0.0178	1.22	1.05	1.33	-24.4	11.5	21.65	0.05
RING380	150.444	1.863	0.0183	0.6	0.5	0.71	-21.6	10.2	22.11	0.07
RING381	150.425	2.778	0.0201	0.32	0.22	0.41	-21.5	10.3	20.16	0.02
RING382	150.416	2.788	0.0202	0.34	0.24	0.44	-21.8	10.4	20.05	0.02
RING383	150.415	2.774	0.0201	0.81	0.67	0.9	-22.6	10.6	21.36	0.04
RING384	150.422	2.210	0.0167	1.25	1.06	1.39	-22.9	10.8	22.34	0.08
RING385	150.441	1.600	0.0195	0.46	0.34	0.54	-20.4	9.7	21.76	0.06
RING386	150.425	1.621	0.0193	1.03	0.91	1.09	-22.9	10.9	21.91	0.06
RING387	150.470	1.947	0.0170	1.54	1.2	1.7	-23.1	10.9	23.06	0.15
RING388	150.454	1.943	0.0173	0.43	0.3	0.52	-19.8	9.5	22.32	0.09
RING389	150.435	1.923	0.0177	0.3	0.17	0.4	-21.6	10.5	19.80	0.02
RING390	150.444	2.511	0.0198	1.5	0.79	1.74	-23.6	11.1	22.65	0.12
RING391	150.423	2.528	0.0202	0.91	0.74	1.65	-21.4	10.1	23.11	0.16
RING393	150.425	2.862	0.0208	1.18	1	1.21	-22.7	10.7	23.26	0.16
RING394	150.478	2.271	0.0168	0.86	0.77	0.92	-23.1	11.0	21.31	0.04
RING395	150.435	2.260	0.0174	0.68	0.59	0.76	-20.0	9.6	23.08	0.16
RING396	150.475	1.639	0.0190	0.99	0.87	1.08	-22.4	10.7	22.10	0.07
RING397	150.480	1.681	0.0189	0.56	0.43	0.66	-19.4	9.4	23.02	0.15
RING398	150.428	2.559	0.0201	1.25	1.18	1.36	-24.4	11.3	22.13	0.08
RING399	150.477	2.002	0.0174	0.97	0.85	1.05	-22.4	10.7	22.21	0.08
RING400	150.457	1.696	0.0187	0.88	0.81	0.95	-23.8	11.3	20.81	0.03
RING401	150.446	1.732	0.0188	0.98	0.74	1.08	-24.1	11.2	21.04	0.04
RING402	150.458	2.614	0.0204	1.29	0.75	1.44	-23.2	10.9	22.95	0.11
RING403	150.450	2.645	0.0207	0.1	0	0.17	-18.8	9.1	20.65	0.03
RING404	150.490	2.031	0.0176	1.07	0.89	1.16	-23.7	11.0	21.62	0.05
RING405	150.481	2.011	0.0174	0.69	0.58	0.72	-21.3	10.1	22.75	0.09
RING406	150.464	2.030	0.0179	0.69	0.57	0.76	-20.7	9.9	22.36	0.09
RING407	150.490	2.358	0.0181	0.69	0.58	0.78	-23.3	10.9	20.68	0.03
RING408	150.479	1.752	0.0192	1.02	0.76	1.1	-22.9	10.7	22.42	0.09
RING409	150.493	2.690	0.0207	0.68	0.53	0.7	-21.0	10.0	22.00	0.07
RING410	150.489	1.826	0.0189	1.72	1.44	1.87	-24.8	11.5	22.69	0.11
RING410	150.489	1.826	0.0189	1.53	1.47	1.95	-22.5	10.6	24.36	0.28
RING411	150.501	1.829	0.0190	0.92	0.86	0.98	-22.9	10.9	21.51	0.05
RING412	150.462	1.838	0.0188	1.28	1.07	1.39	-23.9	11.1	22.38	0.08
RING413	150.479	2.405	0.0186	0.97	0.75	1.04	-22.9	10.7	21.78	0.06
RING413	150.479	2.404	0.0186	0.96	0.86	1.05	-23.5	11.0	21.55	0.05
RING414	150.478	2.434	0.0188	1.14	0.8	1.47	-21.2	10.1	23.55	0.23
RING415	150.450	2.392	0.0188	0.69	0.54	0.76	-21.8	10.2	22.19	0.07
RING416	150.481	2.740	0.0201	0.72	0.63	0.76	-23.0	10.9	20.95	0.03
RING417	150.493	2.116	0.0174	1	0.9	1.06	-22.9	11.1	21.76	0.06
RING418	150.476	2.171	0.0164	1.23	1.06	1.39	-22.4	10.6	23.02	0.10
RING419	150.462	2.157	0.0166	0.92	0.75	1	-23.0	10.8	21.81	0.05
RING420	150.512	2.485	0.0185	0.91	0.7	1.04	-22.6	10.6	22.06	0.07
RING421	150.486	2.486	0.0189	1.75	1.58	1.87	-24.1	11.3	23.35	0.19
RING422	150.473	1.890	0.0176	0.72	0.64	0.81	-22.4	10.6	21.49	0.05
RING423	150.517	2.776	0.0204	0.21	0.14	0.28	-22.4	10.8	-99.00	-99.00
RING424	150.508	2.777	0.0203	0.3	0.26	0.4	-19.4	9.3	21.98	0.07
RING425	150.476	2.769	0.0200	0.66	0.61	0.74	-22.8	10.9	21.03	0.04
RING426	150.493	2.543	0.0191	0.61	0.59	0.72	-20.7	9.8	22.27	0.08

RING427	150.492	2.539	0.0191	0.91	0.74	1.05	-22.1	10.4	22.37	0.09
RING428	150.485	2.539	0.0192	0.97	0.87	1.16	-23.4	10.9	21.62	0.05
RING429	150.521	1.908	0.0177	1.18	0.75	1.31	-23.6	11.1	22.26	0.08
RING430	150.474	1.908	0.0173	0.71	0.62	0.75	-22.7	11.0	20.75	0.03
RING431	150.487	2.824	0.0210	1.24	0.75	1.51	-22.1	10.4	23.27	0.18
RING432	150.496	1.628	0.0196	0.84	0.73	1.13	-21.6	10.2	22.43	0.09
RING433	150.475	1.639	0.0190	0.99	0.87	1.08	-22.4	10.7	22.10	0.07
RING434	150.519	1.647	0.0199	0.93	0.79	1.11	-22.5	10.6	22.61	0.11
RING435	150.520	2.265	0.0162	0.95	0.79	1.02	-23.5	11.0	21.28	0.04
RING436	150.508	2.003	0.0171	0.97	0.74	1.15	-22.7	10.6	21.91	0.06
RING437	150.542	1.709	0.0201	0.16	0.01	0.22	-18.8	9.1	21.16	0.04
RING438	150.508	2.003	0.0171	0.97	0.74	1.15	-22.7	10.6	21.91	0.06
RING439	150.506	2.021	0.0173	0.76	0.64	0.84	-21.1	10.0	22.34	0.09
RING440	150.492	2.011	0.0173	0.9	0.84	0.94	-23.1	11.0	21.44	0.05
RING441	150.525	2.636	0.0196	0.53	0.42	0.59	-22.2	10.5	20.90	0.03
RING443	150.533	1.768	0.0197	0.96	0.86	1.06	-23.4	11.0	21.99	0.07
RING444	150.496	1.745	0.0195	0.29	0.21	0.33	-22.3	10.6	19.50	0.01
RING445	150.515	2.408	0.0183	0.86	0.79	0.93	-22.4	10.6	21.89	0.06
RING446	150.514	2.405	0.0183	0.81	0.72	0.88	-22.5	10.6	22.21	0.08
RING447	150.535	2.401	0.0182	1.16	1.05	1.28	-22.8	10.9	22.61	0.11
RING447	150.535	2.401	0.0182	1.21	1.06	1.38	-22.2	10.6	22.86	0.13
RING448	150.536	1.782	0.0196	0.56	0.45	0.69	-19.9	9.5	22.57	0.08
RING449	150.515	2.126	0.0173	1.11	0.92	1.36	-23.2	10.8	22.47	0.10
RING450	150.521	2.461	0.0184	0.55	0.45	0.58	-23.4	11.3	19.97	0.02
RING451	150.517	2.776	0.0204	0.21	0.14	0.28	-22.4	10.8	-99.00	-99.00
RING452	150.542	2.508	0.0185	1.45	1.16	1.62	-24.9	11.5	22.01	0.07
RING453	150.554	2.532	0.0183	1.26	1.18	1.33	-24.4	11.5	22.21	0.08
RING454	150.577	2.245	0.0167	0.7	0.65	1.08	-20.8	9.9	22.53	0.10
RING455	150.544	2.235	0.0162	0.82	0.72	1.57	-21.0	10.0	22.40	0.09
RING456	150.570	1.624	0.0213	0.76	0.69	0.81	-23.0	10.9	20.91	0.03
RING457	150.541	1.952	0.0173	1.04	0.94	1.2	-23.0	10.8	22.41	0.09
RING458	150.539	1.969	0.0171	1.02	0.87	1.12	-22.6	10.6	22.30	0.09
RING460	150.556	2.270	0.0164	1.89	1.51	2.07	-23.3	10.9	23.19	0.17
RING461	150.549	2.304	0.0166	0.42	0.29	0.51	-19.9	9.5	22.13	0.08
RING462	150.560	1.680	0.0203	0.37	0.28	0.44	-21.6	10.2	20.68	0.03
RING463	150.580	2.616	0.0182	0.17	0.11	0.29	-20.9	10.3	19.19	0.01
RING464	150.549	2.014	0.0170	0.84	0.69	0.95	-22.3	10.5	21.86	0.06
RING465	150.553	2.345	0.0175	0.37	0.29	0.39	-20.2	9.6	21.54	0.05
RING466	150.586	2.080	0.0171	0.8	0.67	1.07	-21.8	10.3	21.83	0.06
RING467	150.561	2.062	0.0173	0.6	0.56	0.7	-22.7	10.7	21.22	0.04
RING468	150.615	2.417	0.0185	0.19	0	0.27	-19.4	9.3	21.12	0.03
RING469	150.558	2.399	0.0181	0.6	1.45	2.17	-23.2	10.9	21.93	0.06
RING470	150.595	2.708	0.0199	1.07	0.98	1.21	-23.4	10.9	22.46	0.10
RING471	150.594	2.107	0.0169	1.03	0.89	1.08	-23.2	11.0	21.61	0.05
RING472	150.572	2.144	0.0169	1.05	1.01	1.26	-23.0	10.7	22.54	0.10
RING473	150.590	2.452	0.0185	0.69	0.56	0.77	-22.5	10.6	21.44	0.05
RING474	150.619	1.842	0.0206	1.37	1.28	1.59	-22.0	10.3	23.47	0.22
RING475	150.571	1.843	0.0200	0.6	0.54	0.7	-21.5	10.2	22.20	0.08
RING476	150.597	2.754	0.0201	0.32	0.27	0.42	-21.7	10.3	20.35	0.02

RING477	150.611	2.791	0.0204	0.94	0.87	1	-22.7	10.7	21.95	0.07
RING478	150.585	2.756	0.0202	0.44	0.38	0.58	-21.2	10.0	21.28	0.04
RING479	150.604	2.504	0.0187	1.05	0.89	1.21	-22.8	10.6	22.46	0.11
RING480	150.602	2.510	0.0187	1.14	1.04	1.43	-22.4	10.5	22.20	0.08
RING480	150.603	2.510	0.0187	1.26	1.14	1.71	-20.8	9.9	24.50	0.32
RING481	150.578	2.480	0.0185	1.1	0.99	1.42	-22.6	10.6	23.18	0.17
RING482	150.603	1.877	0.0201	0.92	0.8	1.15	-21.2	10.0	23.05	0.12
RING483	150.630	2.204	0.0173	0.12	0.02	0.21	-17.8	8.7	21.63	0.05
RING484	150.623	2.245	0.0177	0.9	0.7	1.1	-21.8	10.3	22.57	0.10
RING485	150.622	2.553	0.0186	0.8	0.69	0.93	-22.2	10.5	22.02	0.07
RING486	150.606	2.548	0.0184	0.75	0.74	1.3	-21.6	10.2	22.87	0.13
RING487	150.616	2.550	0.0186	1.5	1.2	1.95	-22.3	10.5	24.51	0.22
RING488	150.631	2.581	0.0188	0.91	0.79	1.02	-20.7	9.8	22.97	0.14
RING489	150.644	2.615	0.0194	0.69	0.54	0.72	-23.0	10.7	20.89	0.03
RING490	150.631	2.618	0.0189	1.03	0.91	1.1	-22.3	10.7	22.54	0.10
RING491	150.645	2.026	0.0176	0.85	0.76	0.94	-22.3	10.6	21.79	0.06
RING492	150.657	2.341	0.0190	0.96	0.84	1.05	-21.7	10.4	22.93	0.13
RING493	150.647	1.728	0.0217	0.75	0.72	1.47	-20.7	9.9	22.76	0.12
RING494	150.620	2.397	0.0185	0.7	0.5	0.71	-22.6	10.6	21.27	0.04
RING495	150.640	1.775	0.0212	1.47	1.29	1.65	-23.3	11.0	22.83	0.13
RING496	150.625	1.773	0.0210	0.18	0.11	0.25	-19.7	9.5	20.28	0.02
RING497	150.635	2.106	0.0166	1.21	0.93	1.76	-22.4	10.5	22.86	0.13
RING498	150.633	2.136	0.0165	0.39	0.31	0.45	-22.9	10.9	20.00	0.02
RING499	150.661	1.858	0.0206	1.11	0.99	1.22	-23.6	11.0	22.08	0.07
RING500	150.667	2.456	0.0195	1.05	0.95	1.11	-22.3	10.5	22.60	0.10
RING501	150.642	2.423	0.0190	0.72	0.66	0.84	-22.7	11.0	21.58	0.05
RING502	150.648	2.413	0.0190	0.18	0.11	0.28	-18.8	9.1	21.34	0.04
RING503	150.678	2.185	0.0178	0.84	0.7	0.92	-22.1	10.5	21.85	0.06
RING504	150.648	2.509	0.0193	1	0.9	1.05	-22.2	10.5	22.43	0.09
RING505	150.666	1.876	0.0202	0.37	0.26	0.43	-20.2	9.7	21.59	0.05
RING506	150.679	1.888	0.0200	0.87	0.7	0.95	-22.7	10.8	21.67	0.05
RING507	150.672	2.817	0.0203	0.48	0.41	0.58	-22.3	10.5	20.68	0.03
RING508	150.664	2.820	0.0204	0.84	0.67	1.02	-22.4	10.5	22.12	0.07
RING509	150.662	1.635	0.0231	0.98	0.77	1.07	-22.9	10.8	22.08	0.07
RING510	150.649	2.571	0.0193	0.4	0.29	0.46	-21.9	10.7	20.30	0.02
RING511	150.654	2.557	0.0195	1.02	0.68	1.1	-21.6	10.2	23.01	0.15
RING512	150.652	2.536	0.0195	0.85	0.76	0.98	-22.3	10.8	22.10	0.07
RING513	150.642	2.527	0.0193	0.37	0.29	0.43	-21.0	10.0	20.82	0.03
RING514	150.687	1.921	0.0195	0.92	0.83	1.02	-23.6	11.0	21.45	0.05
RING515	150.668	1.967	0.0186	0.5	0.39	0.57	-22.7	10.8	20.27	0.02
RING516	150.656	1.661	0.0226	1.23	1.05	1.47	-23.9	11.1	22.23	0.08
RING517	150.694	2.291	0.0195	0.97	0.83	1.03	-22.9	10.7	22.05	0.06
RING518	150.675	2.294	0.0192	0.22	0.18	0.26	-22.1	10.4	-99.00	-99.00
RING519	150.649	2.571	0.0193	0.4	0.29	0.46	-21.9	10.7	20.30	0.02
RING520	150.652	2.580	0.0194	0.17	0.14	0.28	-20.8	10.2	19.59	0.02
RING521	150.671	2.327	0.0193	1.17	1.02	1.33	-23.1	10.8	23.27	0.13
RING522	150.703	2.065	0.0179	1.01	0.9	1.06	-23.9	11.3	21.04	0.04
RING523	150.662	2.045	0.0176	1.19	1.16	1.42	-21.7	10.3	23.27	0.18
RING524	150.714	1.754	0.0215	0.69	0.6	0.75	-21.9	10.6	21.83	0.05

RING525	150.714	2.680	0.0215	0.33	0.28	0.42	-20.5	9.8	20.99	0.03
RING526	150.690	2.755	0.0207	0.74	0.67	0.99	-21.8	10.3	22.16	0.08
RING527	150.703	2.139	0.0179	1.03	0.95	1.21	-22.6	10.6	22.29	0.10
RING528	150.708	2.132	0.0180	1.42	1.09	1.64	-24.5	11.4	22.63	0.11
RING529	150.701	1.889	0.0201	0.78	0.64	0.86	-22.5	10.6	21.44	0.05
RING530	150.730	2.553	0.0209	0.48	0.38	0.57	-20.3	9.7	22.05	0.06
RING531	150.688	2.558	0.0204	1.29	1.05	1.59	-22.1	10.4	23.82	0.22
RING532	150.729	2.779	0.0213	0.55	0.42	0.59	-21.6	10.5	20.98	0.03
RING533	150.720	2.779	0.0212	0.94	0.83	1.03	-22.8	10.8	21.69	0.06
RING534	150.710	2.237	0.0190	0.82	0.75	0.9	-22.9	10.7	21.63	0.05
RING535	150.711	2.226	0.0188	1.13	0.98	1.69	-21.7	10.2	22.65	0.11
RING536	150.707	1.589	0.0241	0.89	0.75	0.99	-23.0	10.8	21.66	0.05
RING537	150.734	1.927	0.0195	0.67	0.53	0.74	-22.3	10.7	21.11	0.04
RING538	150.720	1.965	0.0190	0.37	0.33	0.49	-22.3	10.5	20.21	0.02
RING539	150.687	1.921	0.0195	0.92	0.83	1.02	-23.6	11.0	21.45	0.05
RING540	150.710	2.237	0.0190	0.82	0.75	0.9	-22.9	10.7	21.63	0.05
RING541	150.707	1.648	0.0230	0.83	0.77	0.89	-23.2	11.0	21.00	0.03
RING542	150.718	1.655	0.0228	0.76	0.67	0.83	-22.3	10.6	21.61	0.05
RING543	150.720	1.965	0.0190	0.37	0.33	0.49	-22.3	10.5	20.21	0.02
RING544	150.712	2.015	0.0186	0.66	0.52	0.74	-21.8	10.3	21.51	0.05
RING545	150.764	2.336	0.0204	0.78	0.66	1.12	-21.2	10.0	22.67	0.12
RING546	150.738	2.291	0.0199	0.63	0.48	0.71	-23.2	11.0	20.48	0.03
RING547	150.715	2.293	0.0197	1.3	1.04	1.37	-23.9	11.3	22.08	0.07
RING548	150.713	1.724	0.0217	0.69	0.53	0.75	-23.1	10.8	20.93	0.03
RING549	150.750	2.639	0.0217	1.02	0.9	1.02	-24.6	11.4	21.91	0.06
RING550	150.736	2.626	0.0215	0.99	0.89	1.09	-22.2	10.5	23.11	0.16
RING551	150.719	2.031	0.0184	1.06	0.91	1.21	-22.5	10.6	22.99	0.15
RING552	150.749	2.358	0.0204	0.81	0.71	1.08	-21.0	10.0	22.91	0.14
RING553	150.730	2.347	0.0202	0.96	0.9	1.06	-24.1	11.2	21.62	0.05
RING554	150.755	2.674	0.0219	1.03	0.95	1.13	-22.6	10.6	22.19	0.08
RING555	150.747	2.666	0.0219	0.98	0.84	1.03	-23.2	11.2	21.59	0.05
RING556	150.737	2.672	0.0218	0.61	0.48	0.68	-21.6	10.2	21.89	0.06
RING557	150.738	2.084	0.0181	0.46	0.35	0.53	-20.6	9.8	21.56	0.05
RING558	150.764	2.442	0.0208	0.72	0.58	0.77	-22.9	10.7	21.12	0.04
RING559	150.740	2.406	0.0205	0.98	0.73	1.15	-23.5	11.0	21.73	0.06
RING560	150.779	1.860	0.0213	0.3	0	0.4	-20.3	9.7	21.21	0.04
RING561	150.743	1.876	0.0207	0.84	0.69	0.99	-22.1	10.4	21.91	0.06

Table 5:

Ring ID	k_mag	k_mag_err	u_mag	u_mag_err	g_mag	g_mag_err	r_mag	r_mag_err	i_mag	i_mag_err	z_mag	z_mag_err
RING1	18.79	0.02	23.61	0.47	22.20	0.05	20.91	0.02	20.50	0.03	20.19	0.11
RING2	20.60	0.10	24.30	0.88	22.35	0.06	21.51	0.04	21.10	0.04	21.15	0.25
RING3	18.60	0.02	22.38	0.15	21.63	0.03	20.54	0.02	20.05	0.02	19.48	0.05
RING4	19.74	0.04	23.33	0.36	22.86	0.09	21.74	0.05	21.17	0.05	20.73	0.17
RING5	19.65	0.04	23.29	0.35	22.85	0.09	21.78	0.05	21.38	0.06	20.40	0.13
RING6	20.41	0.09	24.80	1.39	23.47	0.16	22.24	0.08	21.72	0.08	21.61	0.39
RING7	21.04	0.15	22.45	0.16	22.31	0.06	22.05	0.07	21.72	0.08	22.08	0.60
RING8	21.86	0.32	23.62	0.43	23.17	0.12	22.14	0.07	22.47	0.15	99.00	22.20
RING9	22.18	0.42	24.03	0.59	23.08	0.10	22.78	0.10	22.70	0.19	99.00	22.20
RING10	20.45	0.08	22.51	0.15	22.46	0.06	21.63	0.04	21.38	0.06	21.09	0.19
RING11	19.77	0.05	22.90	0.24	22.96	0.10	22.01	0.06	21.13	0.04	20.88	0.20
RING12	20.70	0.11	23.95	0.64	23.31	0.14	22.57	0.11	21.49	0.06	20.99	0.22
RING13	21.28	0.17	23.34	0.36	23.67	0.19	22.75	0.12	22.31	0.13	21.39	0.31
RING14	22.00	0.33	23.58	0.45	23.74	0.20	24.36	0.54	22.57	0.17	22.94	1.31
RING15	21.09	0.15	22.26	0.14	22.42	0.06	21.83	0.05	21.62	0.07	21.74	0.44
RING16	20.81	0.11	23.12	0.20	23.35	0.13	22.87	0.08	22.14	0.08	21.67	0.26
RING17	19.06	0.02	24.30	0.57	22.88	0.08	22.03	0.04	20.92	0.03	20.30	0.07
RING18	19.11	0.02	22.78	0.19	21.98	0.04	20.88	0.02	20.45	0.02	19.89	0.07
RING19	20.00	0.05	23.26	0.29	22.27	0.05	21.40	0.03	20.97	0.04	20.69	0.14
RING20	20.30	0.08	23.45	0.28	22.96	0.09	22.33	0.06	21.87	0.07	20.58	0.10
RING21	21.16	0.15	23.06	0.28	23.94	0.22	22.98	0.16	23.03	0.29	21.46	0.31
RING22	18.94	0.02	23.15	0.21	22.24	0.05	20.71	0.02	20.15	0.01	19.84	0.05
RING23	18.94	0.02	23.15	0.21	22.24	0.05	20.71	0.02	20.15	0.01	19.84	0.05
RING24	20.54	0.13	99.00	23.50	99.00	23.90	23.57	0.24	22.54	0.14	21.68	0.25
RING25	21.92	0.42	99.00	23.50	24.05	0.26	99.00	23.90	23.50	0.38	21.74	0.39
RING26	20.75	0.14	99.00	23.50	23.66	0.18	23.53	0.23	22.20	0.12	21.32	0.27
RING27	21.12	0.20	22.93	0.22	23.61	0.16	23.42	0.25	99.00	23.00	22.72	0.67
RING28	22.55	0.70	23.43	0.16	25.29	0.74	24.11	0.28	23.78	0.33	99.00	22.20
RING29	22.28	0.56	23.71	0.30	24.26	0.29	99.00	23.90	23.03	0.22	99.00	22.20
RING30	99.00	23.20	23.40	0.22	24.00	0.23	23.41	0.20	23.67	0.40	22.11	0.37
RING31	22.26	0.52	23.99	0.29	24.78	0.47	24.01	0.24	23.58	0.24	21.98	0.26
RING33	21.54	0.28	99.00	23.50	24.46	0.35	23.62	0.17	23.03	0.18	23.30	1.15
RING34	21.41	0.24	23.20	0.35	23.37	0.13	22.50	0.09	22.02	0.10	21.44	0.24
RING35	20.48	0.10	99.00	23.50	24.26	0.30	23.26	0.19	22.15	0.11	21.60	0.28
RING36	22.05	0.53	22.60	0.08	23.29	0.12	22.96	0.10	22.66	0.12	22.26	0.30
RING36	21.75	0.40	23.16	0.13	23.41	0.13	23.40	0.15	22.72	0.12	23.88	1.35
RING37	21.07	0.25	24.02	0.39	23.60	0.16	24.02	0.36	22.93	0.21	21.83	0.29
RING38	22.49	0.71	99.00	23.50	24.33	0.31	22.88	0.13	99.00	23.00	99.00	22.20
RING39	99.00	23.20	24.25	0.59	23.55	0.15	22.88	0.11	22.95	0.23	21.66	0.36
RING39	99.00	23.20	99.00	23.50	25.01	0.33	23.90	0.17	23.73	0.27	22.96	0.67
RING40	23.37	1.39	23.55	0.48	99.00	23.90	24.25	0.46	22.84	0.21	22.04	0.41
RING41	20.55	0.10	24.57	1.22	99.00	23.90	24.02	0.37	22.59	0.17	22.89	0.91
RING42	21.21	0.20	99.00	23.50	24.31	0.23	24.64	0.58	23.40	0.31	22.34	0.36
RING42	21.05	0.24	99.00	23.50	25.68	1.07	24.83	0.92	23.08	0.30	99.00	22.20
RING43	20.13	0.08	24.32	0.44	24.06	0.24	23.75	0.20	22.54	0.11	21.57	0.19
RING44	20.47	0.12	99.00	23.50	24.61	0.44	23.00	0.14	22.53	0.16	21.19	0.24

RING45	21.96	0.49	99.00	23.50	99.00	23.90	25.51	0.99	23.12	0.18	21.96	0.27
RING46	22.25	0.55	23.99	0.44	23.74	0.18	23.65	0.26	23.46	0.36	21.42	0.23
RING47	21.43	0.26	99.00	23.50	25.29	0.74	24.28	0.41	23.62	0.42	22.48	0.75
RING48	20.78	0.14	99.00	23.50	24.75	0.45	24.17	0.37	23.56	0.40	99.00	22.20
RING49	22.14	0.49	23.60	0.23	23.04	0.10	24.42	0.35	22.67	0.13	99.00	22.20
RING50	19.77	0.04	24.26	0.92	23.49	0.15	22.21	0.07	21.12	0.04	21.21	0.19
RING51	22.78	0.75	24.25	0.91	24.50	0.37	25.08	1.00	99.00	23.00	22.01	0.40
RING52	21.46	0.22	23.00	0.29	23.31	0.13	23.22	0.18	22.16	0.11	21.86	0.35
RING53	22.27	0.59	23.43	0.37	24.05	0.26	99.00	23.90	23.79	0.50	21.90	0.46
RING54	22.45	0.77	23.69	0.47	24.15	0.29	99.00	23.90	99.00	23.00	99.00	22.20
RING55	21.01	0.15	23.31	0.33	23.26	0.13	23.33	0.19	22.22	0.12	21.27	0.26
RING56	22.20	0.59	99.00	23.50	24.47	0.39	23.13	0.16	23.12	0.27	21.45	0.30
RING57	21.04	0.19	99.00	23.50	24.25	0.32	23.67	0.25	22.26	0.12	21.72	0.39
RING58	21.33	0.22	23.85	0.55	23.49	0.16	23.55	0.23	22.81	0.20	99.00	22.20
RING59	21.14	0.20	99.00	23.50	24.47	0.39	23.99	0.34	23.91	0.56	99.00	22.20
RING60	20.74	0.13	99.00	23.50	23.66	0.19	24.69	0.65	24.19	0.72	21.32	0.27
RING61	20.78	0.15	24.44	0.88	25.04	0.62	24.38	0.46	22.28	0.12	21.32	0.25
RING62	20.44	0.12	23.44	0.20	24.29	0.30	22.95	0.10	22.46	0.10	21.67	0.19
RING63	21.12	0.19	23.20	0.16	23.67	0.17	23.03	0.10	23.58	0.29	23.07	0.83
RING64	20.13	0.08	24.43	0.66	23.25	0.12	22.79	0.12	21.98	0.09	22.89	0.91
RING65	21.79	0.35	23.50	0.28	25.02	0.58	24.54	0.59	22.90	0.22	21.27	0.20
RING66	21.30	0.22	22.99	0.15	24.39	0.33	23.43	0.14	24.04	0.51	22.36	0.55
RING67	21.29	0.24	23.23	0.23	22.85	0.08	22.64	0.09	21.25	0.05	21.71	0.27
RING68	20.70	0.14	23.52	0.30	23.93	0.21	23.88	0.27	22.54	0.15	22.64	0.63
RING69	21.71	0.36	99.00	23.50	99.00	23.90	23.40	0.18	23.62	0.40	99.00	22.20
RING70	20.26	0.09	99.00	23.50	23.96	0.22	23.03	0.13	22.27	0.11	22.77	0.71
RING71	22.17	0.53	23.39	0.27	24.00	0.23	23.99	0.30	23.88	0.51	23.27	1.13
RING72	22.12	0.46	23.66	0.46	22.78	0.08	22.03	0.06	21.92	0.09	21.71	0.38
RING73	99.00	23.20	99.00	23.50	24.38	0.36	99.00	23.90	99.00	23.00	22.37	0.71
RING74	19.63	0.05	24.20	0.75	99.00	23.90	23.53	0.23	22.56	0.16	21.19	0.24
RING75	21.83	0.36	22.71	0.19	23.27	0.13	22.68	0.10	22.14	0.11	22.56	0.84
RING77	20.18	0.09	23.25	0.30	23.91	0.21	23.43	0.26	22.00	0.11	21.19	0.17
RING78	20.42	0.11	23.77	0.27	23.12	0.10	23.30	0.14	22.51	0.11	21.32	0.13
RING79	20.51	0.18	24.62	0.82	23.60	0.16	99.00	23.90	24.49	0.88	21.68	0.26
RING80	99.00	23.20	99.00	23.50	24.70	0.43	24.35	0.42	23.10	0.25	99.00	22.20
RING81	20.81	0.21	24.64	0.84	23.72	0.18	24.25	0.38	22.63	0.16	22.72	0.68
RING82	21.33	0.37	23.12	0.21	22.66	0.07	21.96	0.05	21.93	0.08	21.62	0.25
RING83	21.32	0.27	24.17	0.34	23.96	0.22	22.73	0.08	22.53	0.11	22.26	0.39
RING84	99.00	23.20	24.36	0.30	24.18	0.22	99.00	23.90	23.57	0.22	22.59	0.33
RING85	20.57	0.13	23.46	0.17	25.05	0.59	22.80	0.09	21.93	0.06	21.52	0.15
RING86	19.74	0.06	99.00	23.50	23.26	0.13	22.69	0.11	21.90	0.09	21.72	0.39
RING87	19.76	0.06	99.00	23.50	23.81	0.21	23.88	0.31	22.21	0.12	21.55	0.33
RING88	21.61	0.31	99.00	23.50	24.62	0.44	23.77	0.28	22.89	0.22	21.75	0.40
RING89	22.57	0.65	23.98	0.32	23.72	0.18	23.55	0.15	23.51	0.26	99.00	22.20
RING90	21.19	0.20	23.74	0.43	24.48	0.32	23.24	0.19	22.30	0.13	21.28	0.16
RING91	21.81	0.38	25.20	1.14	24.27	0.29	23.00	0.15	22.66	0.17	22.01	0.35
RING92	21.82	0.40	99.00	23.50	99.00	23.90	23.81	0.31	99.00	23.00	99.00	22.20
RING93	22.00	0.44	99.00	23.50	24.71	0.44	99.00	23.90	23.76	0.47	22.52	0.56
RING94	21.46	0.28	99.00	23.50	24.20	0.27	24.69	0.70	23.42	0.35	99.00	22.20

RING95	21.11	0.33	23.63	0.24	24.83	0.48	23.84	0.20	23.49	0.23	22.74	0.43
RING96	19.22	0.05	24.42	0.49	23.60	0.16	22.21	0.05	21.18	0.03	20.72	0.07
RING97	22.66	1.32	23.71	0.25	24.16	0.26	23.47	0.14	22.87	0.13	21.97	0.21
RING98	21.16	0.33	99.00	23.50	99.00	23.90	24.18	0.27	23.39	0.21	99.00	22.20
RING99	20.66	0.11	99.00	23.50	24.43	0.35	23.37	0.21	22.68	0.18	22.10	0.44
RING100	20.51	0.09	23.73	0.57	24.30	0.31	23.45	0.22	23.18	0.28	22.98	0.99
RING101	21.88	0.35	22.93	0.17	23.63	0.16	23.80	0.30	22.25	0.12	99.00	22.20
RING102	20.68	0.13	24.19	0.71	23.45	0.14	22.49	0.11	22.13	0.13	21.89	0.32
RING103	20.10	0.07	99.00	23.50	99.00	23.90	23.92	0.35	22.53	0.15	22.24	0.43
RING104	22.05	0.53	99.00	23.50	23.90	0.21	23.61	0.26	23.86	0.52	22.11	0.38
RING105	21.60	0.32	23.85	0.39	24.08	0.24	23.45	0.22	22.70	0.18	22.16	0.46
RING106	22.66	0.76	99.00	23.50	99.00	23.90	24.22	0.45	24.17	0.71	99.00	22.20
RING107	21.32	0.21	23.45	0.35	24.24	0.28	23.20	0.21	22.68	0.20	22.70	0.93
RING108	20.13	0.08	24.32	0.44	24.06	0.24	23.75	0.20	22.54	0.11	21.57	0.19
RING109	22.99	0.90	24.40	1.04	23.93	0.22	24.25	0.46	22.54	0.16	21.66	0.29
RING110	21.61	0.24	23.91	0.54	23.62	0.16	23.27	0.22	22.05	0.11	22.12	0.54
RING111	19.43	0.05	23.85	0.55	23.01	0.10	21.85	0.05	20.81	0.03	20.74	0.16
RING112	22.45	0.77	23.69	0.47	24.15	0.29	99.00	23.90	99.00	23.00	99.00	22.20
RING113	21.32	0.25	23.57	0.42	23.75	0.20	24.12	0.39	23.04	0.25	21.46	0.31
RING114	21.90	0.43	99.00	23.50	25.42	0.84	23.76	0.24	22.46	0.14	21.83	0.30
RING115	20.66	0.12	99.00	23.50	25.62	1.00	23.92	0.33	22.68	0.18	22.80	0.83
RING116	20.91	0.21	24.19	0.55	23.73	0.18	23.40	0.18	22.99	0.22	21.58	0.24
RING117	21.81	0.42	23.91	0.43	23.21	0.11	22.29	0.06	22.24	0.11	23.08	0.95
RING118	20.31	0.09	22.30	0.12	22.88	0.08	22.06	0.07	21.52	0.07	21.43	0.29
RING119	20.27	0.09	23.84	0.31	23.60	0.16	22.90	0.10	23.00	0.18	21.64	0.20
RING120	20.63	0.13	23.87	0.34	23.31	0.12	22.80	0.13	22.56	0.16	22.27	0.44
RING121	20.19	0.17	99.00	23.50	23.70	0.17	23.25	0.15	22.48	0.14	22.50	0.56
RING122	20.89	0.14	23.55	0.39	23.20	0.11	22.79	0.14	21.80	0.09	21.87	0.43
RING123	21.39	0.24	23.19	0.28	23.90	0.21	23.41	0.25	23.25	0.35	22.14	0.56
RING124	20.75	0.13	99.00	23.50	24.87	0.62	99.00	23.90	22.70	0.22	22.26	0.47
RING125	20.86	0.11	99.00	23.50	24.28	0.29	23.24	0.12	22.43	0.10	21.65	0.19
RING126	21.75	0.35	99.00	23.50	23.86	0.20	23.72	0.29	22.95	0.22	22.18	0.40
RING127	22.60	1.08	23.74	0.26	23.46	0.14	23.16	0.11	22.72	0.11	23.67	1.02
RING128	21.27	0.20	23.61	0.41	24.10	0.25	23.97	0.42	22.51	0.18	99.00	22.20
RING129	22.68	0.76	99.00	23.50	24.27	0.29	22.81	0.13	22.57	0.16	22.78	0.70
RING130	20.36	0.09	99.00	23.50	23.60	0.20	22.99	0.17	22.93	0.27	22.89	0.85
RING131	20.14	0.08	24.79	1.19	23.93	0.26	22.93	0.16	21.99	0.12	21.31	0.20
RING132	19.73	0.05	23.32	0.31	22.96	0.11	22.29	0.09	21.99	0.11	21.25	0.19
RING133	20.47	0.09	23.29	0.23	22.93	0.09	23.08	0.16	21.89	0.09	21.73	0.31
RING134	19.33	0.04	23.46	0.42	23.15	0.13	22.02	0.07	21.10	0.04	20.50	0.11
RING135	19.49	0.04	23.01	0.28	24.23	0.34	22.17	0.08	21.22	0.05	20.62	0.12
RING136	21.38	0.23	99.00	23.50	23.71	0.18	22.85	0.13	22.02	0.10	23.18	1.19
RING137	20.87	0.15	99.00	23.50	24.08	0.30	23.00	0.16	22.17	0.12	99.00	22.20
RING138	21.38	0.27	99.00	23.50	23.50	0.15	23.84	0.26	22.20	0.11	21.82	0.30
RING139	21.42	0.24	99.00	23.50	23.65	0.17	22.97	0.17	22.69	0.21	21.70	0.37
RING140	17.50	0.01	21.77	0.06	19.92	0.01	19.01	0.01	18.55	0.01	18.22	0.01
RING141	20.49	0.09	24.11	0.50	23.35	0.13	22.75	0.12	22.22	0.12	21.06	0.17
RING142	20.31	0.08	99.00	23.50	24.17	0.26	22.90	0.13	22.19	0.11	21.66	0.29
RING143	21.31	0.26	24.18	0.38	24.65	0.41	23.87	0.21	22.85	0.14	23.03	0.64

RING144	20.77	0.11	99.00	23.50	24.33	0.37	24.29	0.53	22.54	0.16	99.00	22.20
RING145	21.16	0.20	23.26	0.30	22.59	0.06	21.81	0.06	21.78	0.09	20.48	0.12
RING146	18.57	0.02	23.20	0.28	22.72	0.09	21.23	0.04	20.40	0.03	19.98	0.06
RING147	21.09	0.32	23.57	0.22	23.29	0.12	22.65	0.07	23.17	0.19	22.74	0.56
RING148	20.63	0.12	22.41	0.09	21.68	0.03	21.33	0.03	21.01	0.04	21.27	0.17
RING149	20.90	0.15	24.60	0.66	24.01	0.23	24.11	0.42	22.22	0.12	21.84	0.30
RING150	21.33	0.25	99.00	23.50	23.80	0.19	24.80	0.57	23.61	0.30	22.40	0.39
RING151	20.30	0.09	22.59	0.16	22.92	0.09	22.14	0.08	21.60	0.08	21.15	0.22
RING152	20.87	0.15	23.12	0.26	99.00	23.90	24.23	0.53	23.67	0.51	21.10	0.21
RING153	20.88	0.26	24.34	0.45	24.40	0.33	23.15	0.11	22.51	0.11	21.57	0.15
RING154	20.07	0.07	24.06	0.29	24.01	0.23	23.53	0.15	22.99	0.14	22.35	0.35
RING155	18.98	0.03	23.07	0.25	22.26	0.06	21.38	0.04	20.59	0.03	20.09	0.06
RING156	19.70	0.06	22.62	0.16	22.21	0.06	21.33	0.04	20.90	0.04	20.93	0.14
RING157	22.06	0.44	23.78	0.31	23.51	0.15	23.41	0.23	22.99	0.23	21.42	0.18
RING158	20.13	0.07	22.96	0.12	23.62	0.16	22.56	0.06	22.02	0.07	99.00	22.20
RING159	18.98	0.03	23.07	0.25	22.26	0.06	21.38	0.04	20.59	0.03	20.09	0.06
RING160	18.32	0.01	23.08	0.14	21.88	0.03	20.65	0.01	20.00	0.01	19.63	0.03
RING161	22.03	0.39	23.12	0.20	23.43	0.14	23.47	0.19	22.48	0.14	21.47	0.27
RING162	19.74	0.05	25.13	1.25	23.30	0.13	22.80	0.10	22.07	0.09	21.38	0.25
RING163	19.22	0.03	99.00	23.50	23.30	0.15	22.16	0.08	21.25	0.05	20.26	0.09
RING164	20.02	0.07	25.00	0.94	23.64	0.16	22.76	0.13	22.33	0.13	21.12	0.13
RING165	20.05	0.09	23.09	0.19	24.30	0.30	23.20	0.15	22.47	0.15	21.74	0.28
RING166	20.40	0.09	99.00	23.50	23.46	0.14	22.92	0.14	22.43	0.14	21.62	0.21
RING167	20.26	0.08	24.27	0.48	23.71	0.17	22.94	0.15	22.63	0.17	99.00	22.20
RING168	18.85	0.03	23.63	0.41	22.85	0.10	21.33	0.04	20.55	0.03	20.27	0.08
RING169	20.97	0.27	22.68	0.13	23.08	0.10	22.68	0.10	22.13	0.11	21.60	0.25
RING170	19.74	0.05	99.00	23.50	23.25	0.12	21.96	0.07	21.35	0.06	21.20	0.23
RING171	20.69	0.13	99.00	23.50	23.17	0.11	22.70	0.13	22.30	0.14	22.08	0.53
RING172	18.99	0.03	99.00	23.50	22.53	0.07	21.27	0.03	20.61	0.03	20.31	0.09
RING173	19.49	0.04	23.42	0.28	23.30	0.12	21.78	0.04	20.94	0.03	20.53	0.08
RING174	18.90	0.02	22.09	0.08	20.98	0.02	20.20	0.01	19.80	0.01	19.49	0.04
RING175	22.07	0.47	23.89	0.40	24.14	0.27	99.00	23.90	23.33	0.30	23.25	1.42
RING176	18.98	0.03	23.07	0.25	22.26	0.06	21.38	0.04	20.59	0.03	20.09	0.06
RING177	19.01	0.03	99.00	23.50	22.25	0.06	21.18	0.03	20.51	0.03	20.08	0.07
RING178	20.28	0.09	24.65	0.68	23.70	0.17	23.48	0.24	22.24	0.12	21.93	0.28
RING179	19.76	0.05	22.72	0.14	22.98	0.10	21.57	0.03	21.20	0.04	20.65	0.13
RING180	20.03	0.06	23.53	0.29	24.34	0.33	23.62	0.22	22.56	0.15	21.40	0.26
RING181	21.62	0.27	23.70	0.33	23.46	0.15	23.46	0.19	23.10	0.24	21.75	0.36
RING182	20.23	0.08	24.66	1.26	23.62	0.20	22.60	0.11	21.73	0.08	22.04	0.45
RING183	20.29	0.11	99.00	23.50	23.65	0.17	22.60	0.07	22.33	0.09	21.64	0.21
RING184	21.10	0.19	24.44	0.66	23.80	0.20	23.29	0.16	22.54	0.14	21.35	0.25
RING185	21.18	0.19	22.63	0.11	22.52	0.06	22.01	0.06	21.67	0.07	20.98	0.12
RING186	19.33	0.04	24.62	0.52	24.35	0.31	23.23	0.12	21.81	0.05	21.48	0.13
RING187	21.16	0.27	22.97	0.17	23.15	0.11	22.46	0.08	21.86	0.09	22.01	0.36
RING188	21.18	0.21	22.70	0.11	22.32	0.05	21.68	0.03	21.73	0.05	21.87	0.26
RING189	20.04	0.07	23.20	0.18	23.21	0.11	22.71	0.12	21.62	0.07	21.15	0.14
RING190	20.26	0.07	23.31	0.20	23.45	0.14	22.87	0.09	21.72	0.05	21.28	0.17
RING191	20.30	0.08	23.30	0.23	24.03	0.25	23.32	0.17	21.90	0.08	21.84	0.39
RING192	21.22	0.21	23.79	0.31	24.46	0.35	23.12	0.17	22.97	0.23	21.85	0.26

RING193	21.62	0.20	99.00	23.50	24.97	0.42	25.62	1.28	99.00	23.00	99.00	22.20
RING193	21.67	0.24	99.00	23.50	23.91	0.19	24.62	0.58	24.69	1.02	22.66	0.61
RING194	23.05	1.04	23.89	0.59	24.16	0.30	23.00	0.17	22.94	0.27	21.59	0.30
RING195	21.71	0.35	23.91	0.41	24.60	0.42	24.47	0.47	99.00	23.00	99.00	22.20
RING196	19.18	0.03	22.51	0.08	22.14	0.04	21.01	0.02	20.50	0.02	20.05	0.04
RING197	20.91	0.14	22.79	0.12	22.02	0.04	21.59	0.03	21.30	0.04	21.52	0.21
RING198	21.57	0.31	24.28	0.57	24.58	0.41	23.44	0.18	22.87	0.20	22.75	0.89
RING199	20.72	0.14	24.79	0.51	24.17	0.27	24.24	0.29	23.01	0.14	22.72	0.37
RING200	22.17	0.53	99.00	23.50	24.45	0.34	23.96	0.28	23.00	0.18	99.00	22.20
RING201	22.53	0.86	24.59	0.77	23.45	0.14	23.95	0.31	23.04	0.25	21.26	0.18
RING202	21.73	0.55	99.00	23.50	23.80	0.19	24.17	0.37	22.91	0.22	21.65	0.26
RING203	20.85	0.13	99.00	23.50	24.44	0.38	23.56	0.30	22.76	0.22	99.00	22.20
RING204	20.60	0.12	99.00	23.50	25.02	0.58	99.00	23.90	24.06	0.44	99.00	22.20
RING205	21.83	0.32	24.48	1.16	23.27	0.13	23.42	0.26	22.55	0.18	22.42	0.74
RING206	99.00	23.20	99.00	23.50	24.23	0.33	24.49	0.71	24.52	1.05	22.68	0.73
RING207	20.06	0.06	24.28	0.72	22.66	0.08	21.53	0.05	21.32	0.06	20.85	0.14
RING208	20.94	0.16	99.00	23.50	23.93	0.21	24.61	0.68	23.69	0.44	21.27	0.15
RING209	21.02	0.37	99.00	23.50	24.94	0.54	23.94	0.22	23.45	0.24	22.51	0.31
RING210	20.90	0.15	99.00	23.50	25.24	0.81	23.19	0.20	23.66	0.52	22.91	1.00
RING211	20.59	0.12	24.38	0.73	23.91	0.19	23.36	0.15	22.42	0.14	21.57	0.28
RING211	21.21	0.20	23.89	0.44	23.47	0.12	23.12	0.12	22.44	0.13	21.75	0.31
RING212	19.78	0.06	23.15	0.16	22.78	0.08	22.06	0.04	21.27	0.04	20.98	0.13
RING213	20.93	0.16	24.66	1.02	24.52	0.43	99.00	23.90	23.13	0.29	22.25	0.49
RING214	18.74	0.02	23.32	0.20	22.76	0.07	21.21	0.03	20.53	0.03	20.00	0.05
RING215	21.86	0.41	23.67	0.42	99.00	23.90	23.81	0.25	23.48	0.40	21.72	0.35
RING216	21.21	0.21	23.50	0.22	23.63	0.16	23.69	0.20	24.54	0.76	22.84	0.54
RING217	21.04	0.18	22.54	0.13	24.04	0.24	23.19	0.14	22.96	0.18	22.81	0.74
RING218	21.04	0.19	23.97	0.55	23.27	0.12	22.74	0.10	22.13	0.12	21.79	0.38
RING219	20.47	0.09	24.33	0.69	24.54	0.37	23.72	0.22	23.10	0.20	21.66	0.26
RING220	21.92	0.35	22.74	0.23	23.39	0.15	22.83	0.15	22.28	0.14	99.00	22.20
RING221	22.05	0.40	23.52	0.48	23.92	0.24	23.64	0.32	99.00	23.00	99.00	22.20
RING222	21.87	0.33	99.00	23.50	23.88	0.22	23.42	0.17	23.07	0.20	22.18	0.42
RING223	21.68	0.27	23.22	0.36	23.99	0.25	24.29	0.58	22.78	0.23	21.34	0.27
RING224	20.31	0.07	99.00	23.50	24.65	0.42	24.13	0.36	22.52	0.14	21.20	0.16
RING225	20.55	0.10	99.00	23.50	24.67	0.42	23.25	0.17	23.00	0.24	21.52	0.20
RING226	19.89	0.06	25.05	1.11	24.29	0.30	22.85	0.11	21.76	0.06	21.18	0.12
RING227	20.24	0.08	23.81	0.55	22.52	0.07	22.14	0.08	21.28	0.06	21.34	0.23
RING228	18.70	0.02	23.40	0.33	22.56	0.06	20.89	0.02	20.21	0.02	19.66	0.05
RING229	20.47	0.11	99.00	23.50	23.90	0.22	23.91	0.41	22.80	0.22	21.15	0.16
RING230	21.42	0.21	23.08	0.27	23.99	0.23	24.72	0.83	22.57	0.17	21.30	0.18
RING230	22.14	0.38	23.47	0.35	99.00	23.90	23.95	0.37	23.62	0.41	22.01	0.31
RING231	22.78	0.96	99.00	23.50	24.46	0.35	23.81	0.25	22.96	0.19	21.23	0.14
RING232	20.83	0.20	24.78	0.92	99.00	23.90	24.00	0.34	22.64	0.19	21.35	0.18
RING233	21.29	0.23	24.49	0.59	23.44	0.14	23.01	0.14	21.94	0.09	21.23	0.15
RING234	20.83	0.20	24.78	0.92	99.00	23.90	24.00	0.34	22.64	0.19	21.35	0.18
RING235	19.89	0.06	99.00	23.50	23.54	0.17	22.49	0.10	21.81	0.08	22.62	0.88
RING236	21.19	0.25	23.42	0.22	23.75	0.18	23.02	0.14	22.40	0.14	22.00	0.31
RING237	22.35	0.88	22.67	0.13	23.27	0.12	23.20	0.16	22.14	0.12	22.94	0.78
RING238	21.17	0.26	23.70	0.50	23.57	0.16	23.13	0.20	22.29	0.14	21.33	0.19

RING239	19.08	0.04	23.67	0.48	22.46	0.06	21.11	0.03	20.40	0.03	20.05	0.06
RING240	21.45	0.25	23.90	0.32	23.16	0.11	23.09	0.11	23.96	0.40	99.00	22.20
RING241	20.28	0.11	24.94	0.75	23.52	0.15	22.83	0.08	22.15	0.08	21.24	0.11
RING242	21.02	0.21	99.00	23.50	23.92	0.21	25.03	0.87	23.84	0.57	21.89	0.30
RING243	23.19	0.37	24.88	0.34	25.04	0.17	24.45	0.13	25.25	0.52	23.16	0.34
RING243	22.97	0.53	23.98	0.26	24.06	0.12	23.49	0.09	23.76	0.23	22.60	0.34
RING244	19.70	0.06	23.96	0.61	23.25	0.13	22.56	0.11	21.27	0.06	21.16	0.18
RING245	21.48	0.29	23.23	0.22	23.84	0.20	23.71	0.26	22.78	0.21	22.58	0.55
RING246	19.14	0.04	23.07	0.16	23.01	0.09	22.26	0.07	21.31	0.05	20.87	0.11
RING247	19.07	0.03	23.20	0.21	22.42	0.06	20.95	0.02	20.31	0.02	20.19	0.06
RING248	22.82	0.84	24.12	0.71	25.61	1.13	23.70	0.30	99.00	23.00	23.33	1.35
RING249	19.33	0.03	22.86	0.22	22.29	0.06	21.71	0.05	21.45	0.07	20.67	0.12
RING250	21.68	0.41	23.87	0.58	22.82	0.08	23.05	0.19	23.28	0.35	21.34	0.19
RING251	20.54	0.14	99.00	23.50	24.28	0.33	24.53	0.64	22.97	0.27	21.45	0.24
RING252	20.52	0.14	23.80	0.53	24.80	0.54	99.00	23.90	22.46	0.17	22.99	0.98
RING253	19.02	0.04	99.00	23.50	23.12	0.12	21.61	0.05	20.49	0.03	20.33	0.08
RING254	22.11	0.57	99.00	23.50	24.91	0.59	23.24	0.20	22.99	0.27	22.32	0.53
RING255	20.95	0.15	24.81	1.48	23.74	0.20	23.71	0.29	23.08	0.27	22.36	0.69
RING256	21.70	0.36	23.43	0.23	24.40	0.29	23.72	0.24	24.03	0.58	21.50	0.18
RING257	22.23	0.61	24.42	0.84	24.15	0.26	23.81	0.26	23.49	0.38	99.00	22.20
RING258	20.63	0.16	23.82	0.27	24.04	0.24	23.54	0.17	22.61	0.12	21.69	0.18
RING259	20.77	0.15	22.92	0.14	23.77	0.19	22.76	0.11	22.40	0.13	21.48	0.19
RING260	21.22	0.20	99.00	23.50	23.39	0.15	23.51	0.25	22.30	0.13	21.33	0.30
RING261	21.68	0.33	24.34	0.46	23.70	0.17	23.44	0.14	22.44	0.11	99.00	22.20
RING262	21.14	0.20	99.00	23.50	23.91	0.21	23.78	0.27	24.12	0.64	99.00	22.20
RING263	21.40	0.35	99.00	23.50	23.86	0.23	24.13	0.45	23.28	0.35	23.45	1.50
RING264	19.36	0.04	23.59	0.44	99.00	23.90	22.79	0.13	21.60	0.08	21.18	0.19
RING265	20.37	0.09	99.00	23.50	23.48	0.16	22.96	0.14	22.08	0.12	21.41	0.25
RING266	19.02	0.03	23.87	0.51	24.42	0.33	22.69	0.09	21.27	0.05	20.35	0.09
RING267	20.23	0.08	99.00	23.50	24.08	0.25	24.21	0.37	22.74	0.19	22.54	0.71
RING268	21.44	0.38	24.27	0.39	23.89	0.21	23.34	0.14	22.80	0.15	22.57	0.42
RING269	20.19	0.08	23.68	0.50	24.28	0.33	22.82	0.13	22.27	0.12	99.00	22.20
RING270	20.34	0.08	24.00	0.66	24.01	0.26	23.72	0.30	22.01	0.10	20.88	0.20
RING271	20.10	0.10	23.79	0.30	23.33	0.12	23.38	0.18	22.14	0.10	21.27	0.15
RING272	20.17	0.10	24.83	0.78	99.00	23.90	24.40	0.47	22.84	0.20	23.08	0.81
RING273	20.08	0.11	23.45	0.22	23.63	0.16	22.54	0.09	22.21	0.11	21.40	0.17
RING274	20.57	0.17	99.00	23.50	24.00	0.23	23.02	0.13	22.16	0.11	22.08	0.32
RING275	21.02	0.86	99.00	23.50	23.87	0.20	22.72	0.08	22.68	0.13	21.07	0.10
RING276	21.75	0.33	99.00	23.50	24.91	0.52	24.84	0.68	23.72	0.44	99.00	22.20
RING277	20.42	0.11	99.00	23.50	24.94	0.54	23.28	0.16	23.10	0.25	99.00	22.20
RING278	20.11	0.06	99.00	23.50	23.14	0.12	22.28	0.08	21.61	0.07	22.40	0.80
RING279	19.80	0.05	23.47	0.41	24.07	0.27	22.92	0.14	22.12	0.11	22.40	0.80
RING280	22.93	0.89	99.00	23.50	24.38	0.25	23.33	0.16	99.00	23.00	99.00	22.20
RING280	22.91	1.15	99.00	23.50	24.89	0.52	22.98	0.15	23.06	0.30	99.00	22.20
RING281	21.29	1.14	23.99	0.31	24.42	0.33	23.74	0.19	22.26	0.08	21.88	0.18
RING282	19.73	0.08	24.09	0.35	23.99	0.23	22.65	0.07	21.64	0.05	21.05	0.08
RING283	20.45	0.11	24.80	1.34	23.17	0.11	22.39	0.09	21.59	0.08	21.37	0.22
RING284	19.06	0.03	23.74	0.20	23.11	0.10	22.13	0.05	20.91	0.03	20.34	0.05
RING285	21.66	0.33	23.38	0.15	24.42	0.33	23.49	0.16	22.29	0.09	21.81	0.24

RING286	20.25	0.09	24.09	0.44	23.47	0.14	22.47	0.06	22.06	0.07	21.20	0.15
RING287	19.20	0.03	22.89	0.21	22.49	0.06	21.50	0.04	20.77	0.04	20.62	0.12
RING288	20.53	0.12	23.28	0.33	24.59	0.40	23.04	0.16	23.85	0.62	23.38	1.43
RING289	20.04	0.07	24.60	0.99	23.92	0.21	23.07	0.13	22.25	0.12	21.07	0.18
RING290	20.37	0.09	99.00	23.50	23.48	0.16	22.96	0.14	22.08	0.12	21.41	0.25
RING291	19.51	0.04	24.52	0.65	24.34	0.31	22.80	0.12	21.63	0.07	21.21	0.16
RING292	17.73	0.01	22.50	0.15	20.84	0.02	19.55	0.01	19.02	0.01	18.77	0.02
RING293	20.03	0.10	99.00	23.50	24.55	0.38	23.84	0.21	22.81	0.15	21.59	0.19
RING294	17.92	0.01	21.96	0.10	20.23	0.01	19.21	0.01	18.81	0.01	18.58	0.02
RING295	20.54	0.13	24.91	0.84	24.05	0.24	23.29	0.20	23.01	0.23	21.29	0.17
RING296	21.32	0.30	24.30	0.34	24.49	0.36	24.07	0.26	22.68	0.12	22.83	0.48
RING297	19.06	0.02	24.30	0.57	22.88	0.08	22.03	0.04	20.92	0.03	20.30	0.07
RING298	22.34	0.66	23.92	0.53	23.61	0.18	22.64	0.11	22.94	0.27	22.00	0.43
RING299	19.51	0.04	24.52	0.65	24.34	0.31	22.80	0.12	21.63	0.07	21.21	0.16
RING300	21.23	0.21	23.02	0.19	23.27	0.12	22.28	0.06	21.74	0.06	21.64	0.20
RING301	19.46	0.04	23.64	0.31	23.83	0.19	23.49	0.16	22.06	0.08	21.66	0.20
RING302	20.02	0.08	99.00	23.50	24.20	0.30	23.25	0.19	22.95	0.27	21.27	0.22
RING303	20.01	0.09	25.25	1.26	23.85	0.20	23.51	0.22	22.77	0.20	21.31	0.17
RING304	99.00	23.20	23.89	0.36	23.36	0.13	22.83	0.12	22.15	0.11	22.35	0.45
RING305	20.75	0.15	99.00	23.50	23.74	0.19	23.46	0.18	23.34	0.28	21.67	0.28
RING305	21.75	0.26	23.70	0.23	24.79	0.35	24.47	0.32	23.72	0.28	22.08	0.29
RING306	19.93	0.05	99.00	23.50	25.06	0.60	23.23	0.17	22.61	0.14	21.35	0.21
RING307	20.03	0.08	23.16	0.29	22.86	0.09	22.46	0.11	21.33	0.06	21.18	0.17
RING308	20.27	0.11	24.44	0.54	24.22	0.28	23.07	0.16	22.54	0.15	21.23	0.16
RING309	19.05	0.13	23.41	0.18	23.28	0.12	21.82	0.03	20.88	0.02	20.46	0.05
RING310	20.34	0.10	23.16	0.21	23.67	0.17	23.17	0.12	22.83	0.16	21.46	0.17
RING310	23.79	0.66	99.00	23.50	26.33	0.54	26.40	0.66	24.21	0.17	24.57	0.84
RING311	18.77	0.02	23.18	0.29	21.98	0.04	20.88	0.03	20.31	0.02	20.50	0.09
RING312	19.65	0.04	23.04	0.30	22.72	0.07	22.25	0.07	21.30	0.05	20.91	0.14
RING313	20.52	0.10	23.05	0.13	23.61	0.16	23.09	0.12	21.82	0.06	21.42	0.16
RING314	20.30	0.09	23.46	0.39	23.45	0.14	22.89	0.14	21.78	0.09	21.70	0.38
RING315	20.65	0.14	25.45	1.24	23.84	0.20	23.35	0.15	22.27	0.09	21.59	0.17
RING316	19.12	0.04	24.09	0.44	22.26	0.05	21.00	0.02	20.51	0.03	20.17	0.06
RING317	20.29	0.10	25.00	1.45	23.69	0.18	22.29	0.06	21.59	0.07	21.25	0.23
RING318	19.45	0.04	99.00	23.50	24.60	0.39	22.61	0.11	21.52	0.07	21.77	0.41
RING319	19.31	0.04	23.49	0.41	22.64	0.07	21.60	0.05	21.17	0.05	20.43	0.12
RING320	19.86	0.16	99.00	23.50	23.46	0.14	23.59	0.22	22.46	0.14	22.08	0.37
RING321	19.49	0.11	23.91	0.43	23.60	0.16	22.85	0.11	21.70	0.07	21.57	0.23
RING322	19.70	0.05	23.56	0.24	23.46	0.14	22.62	0.11	21.95	0.10	21.31	0.16
RING323	21.68	0.29	23.25	0.24	23.27	0.12	23.35	0.15	22.20	0.11	99.00	22.20
RING324	20.85	0.15	24.55	0.60	24.64	0.41	25.29	0.76	22.13	0.08	21.81	0.25
RING325	19.50	0.04	23.57	0.44	24.22	0.28	22.65	0.12	21.68	0.08	20.80	0.17
RING326	20.10	0.09	99.00	23.50	23.54	0.17	22.90	0.16	22.04	0.11	22.87	0.82
RING327	19.49	0.11	23.91	0.43	23.60	0.16	22.85	0.11	21.70	0.07	21.57	0.23
RING328	19.79	0.15	99.00	23.50	99.00	23.90	22.58	0.09	21.46	0.06	20.92	0.13
RING329	19.14	0.03	99.00	23.50	23.61	0.16	22.13	0.05	21.18	0.04	20.48	0.07
RING330	19.33	0.04	22.20	0.12	21.95	0.04	21.17	0.03	20.56	0.03	20.32	0.08
RING331	19.36	0.04	24.86	1.04	23.69	0.17	22.42	0.07	21.04	0.04	20.66	0.12
RING332	20.32	0.10	21.24	0.06	20.98	0.02	21.07	0.03	20.90	0.04	20.43	0.09

RING333	20.19	0.11	24.51	0.99	24.06	0.26	23.11	0.19	22.52	0.17	21.43	0.22
RING334	19.78	0.05	99.00	23.50	23.12	0.10	22.48	0.07	21.59	0.05	21.44	0.21
RING335	20.47	0.11	25.41	1.33	24.89	0.51	99.00	23.90	24.10	0.63	22.13	0.33
RING336	19.40	0.03	99.00	23.50	25.49	0.89	23.30	0.17	21.85	0.08	21.30	0.18
RING337	20.89	0.15	24.86	0.80	23.21	0.11	22.83	0.13	23.20	0.30	21.96	0.30
RING338	18.74	0.02	99.00	23.50	22.64	0.07	21.20	0.03	20.39	0.02	19.80	0.07
RING339	18.82	0.05	99.00	23.50	22.43	0.06	20.95	0.03	20.35	0.03	20.30	0.08
RING340	18.13	0.01	23.45	0.44	21.63	0.03	20.27	0.01	19.68	0.01	19.45	0.04
RING341	20.91	0.17	23.77	0.30	22.59	0.06	22.22	0.07	21.67	0.07	21.63	0.22
RING342	18.64	0.02	22.72	0.23	21.89	0.04	20.71	0.02	20.19	0.02	19.73	0.05
RING343	19.92	0.06	24.42	1.08	23.86	0.21	22.71	0.11	21.49	0.07	21.26	0.19
RING344	20.44	0.10	23.92	0.69	23.21	0.11	22.52	0.09	21.93	0.10	20.90	0.14
RING345	19.74	0.10	23.84	0.41	23.83	0.20	23.12	0.13	23.30	0.30	21.12	0.18
RING346	20.72	0.14	25.19	0.79	23.94	0.22	23.36	0.15	23.44	0.25	23.06	0.57
RING347	20.60	0.12	99.00	23.50	25.61	0.99	23.34	0.20	23.23	0.31	21.62	0.22
RING348	20.74	0.16	23.47	0.39	23.36	0.13	22.68	0.13	22.70	0.19	99.00	22.20
RING349	20.23	0.09	24.21	0.33	24.08	0.24	23.01	0.10	21.83	0.04	21.26	0.08
RING350	22.10	0.55	24.88	0.86	23.23	0.11	22.98	0.15	22.39	0.13	22.62	0.53
RING351	20.73	0.16	22.88	0.14	22.87	0.08	21.85	0.06	21.38	0.05	22.31	0.40
RING352	21.14	0.20	24.91	0.84	23.89	0.21	23.43	0.22	23.03	0.26	21.16	0.14
RING353	21.14	0.19	99.00	23.50	24.04	0.24	24.34	0.57	22.88	0.25	99.00	22.20
RING354	20.93	0.16	22.86	0.22	21.93	0.04	21.35	0.04	21.53	0.07	21.00	0.14
RING355	20.41	0.10	23.92	0.57	24.03	0.24	22.83	0.14	21.84	0.10	21.80	0.30
RING356	21.54	0.32	23.28	0.14	23.18	0.11	22.41	0.06	22.48	0.11	99.00	22.20
RING357	17.90	0.01	22.39	0.08	20.66	0.01	19.52	0.01	19.03	0.01	18.79	0.01
RING358	20.70	0.15	22.72	0.14	22.02	0.04	21.33	0.03	21.17	0.05	20.80	0.16
RING359	21.22	0.21	99.00	23.50	23.70	0.18	24.37	0.61	23.58	0.43	99.00	22.20
RING360	19.27	0.03	22.94	0.24	21.83	0.03	20.77	0.02	20.38	0.02	19.96	0.08
RING361	21.33	0.24	24.46	0.97	24.00	0.24	24.10	0.47	22.66	0.19	22.08	0.54
RING362	21.52	0.24	25.14	1.21	25.15	0.65	24.30	0.36	99.00	23.00	22.61	0.47
RING363	19.72	0.05	23.76	0.30	23.43	0.14	22.77	0.09	22.32	0.10	22.39	0.36
RING364	22.25	0.18	25.96	1.09	25.09	0.25	24.54	0.21	23.83	0.21	23.72	0.67
RING364	21.05	0.15	23.25	0.23	23.76	0.18	22.69	0.10	22.31	0.13	21.77	0.28
RING365	20.54	0.10	24.00	0.46	24.54	0.37	23.45	0.20	22.78	0.21	21.58	0.24
RING366	20.21	0.10	22.68	0.14	21.26	0.02	20.75	0.02	20.47	0.02	20.16	0.09
RING367	19.75	0.05	23.59	0.51	24.80	0.48	23.28	0.19	21.89	0.10	21.62	0.26
RING368	21.51	0.29	23.39	0.42	99.00	23.90	24.12	0.40	22.99	0.27	99.00	22.20
RING369	19.33	0.04	22.56	0.20	22.71	0.07	22.04	0.06	20.84	0.04	21.42	0.22
RING370	19.42	0.05	22.34	0.08	22.03	0.04	21.71	0.03	21.01	0.03	20.46	0.06
RING371	19.58	0.04	24.18	0.54	23.24	0.12	21.95	0.05	21.47	0.06	20.52	0.09
RING372	20.22	0.08	24.21	0.56	23.45	0.14	22.99	0.13	21.82	0.09	21.40	0.20
RING373	21.68	0.29	23.52	0.29	22.95	0.09	22.02	0.05	21.86	0.09	21.56	0.24
RING374	22.25	0.18	25.96	1.09	25.09	0.25	24.54	0.21	23.83	0.21	23.72	0.67
RING374	21.05	0.15	23.25	0.23	23.76	0.18	22.69	0.10	22.31	0.13	21.77	0.28
RING375	21.86	0.34	22.94	0.17	23.65	0.17	23.41	0.19	22.65	0.18	99.00	22.20
RING376	19.89	0.06	99.00	23.50	23.74	0.18	22.94	0.12	22.12	0.11	21.02	0.14
RING377	99.00	23.20	99.00	23.50	24.22	0.29	23.24	0.22	23.25	0.32	21.95	0.48
RING378	99.00	23.20	22.96	0.18	99.00	23.90	23.85	0.26	23.11	0.27	99.00	22.20
RING379	19.78	0.06	99.00	23.50	23.32	0.12	22.26	0.08	22.12	0.10	20.96	0.12

RING380	21.47	0.31	23.29	0.20	23.47	0.14	22.80	0.13	22.34	0.13	21.97	0.29
RING381	18.88	0.02	22.82	0.16	22.01	0.04	20.81	0.02	20.44	0.02	20.10	0.06
RING382	18.72	0.02	23.38	0.26	22.16	0.04	20.74	0.02	20.27	0.02	19.95	0.05
RING383	20.13	0.08	23.46	0.28	22.86	0.08	22.43	0.08	21.56	0.07	21.07	0.15
RING384	20.74	0.16	23.47	0.39	23.36	0.13	22.68	0.13	22.70	0.19	99.00	22.20
RING385	21.53	0.29	22.96	0.17	23.17	0.11	22.29	0.07	21.66	0.07	21.65	0.30
RING386	19.88	0.06	99.00	23.50	23.67	0.17	23.15	0.15	22.25	0.12	21.32	0.22
RING387	21.02	0.18	23.21	0.19	25.44	0.85	24.04	0.41	24.03	0.59	22.17	0.35
RING388	22.16	0.48	99.00	23.50	24.22	0.28	22.62	0.11	22.62	0.16	22.12	0.34
RING389	18.62	0.02	23.74	0.30	22.18	0.05	20.52	0.02	19.97	0.02	19.57	0.03
RING390	22.55	0.97	99.00	23.50	23.68	0.17	23.48	0.19	22.46	0.12	22.85	0.59
RING391	22.13	0.67	99.00	23.50	24.66	0.42	24.27	0.54	23.01	0.28	99.00	22.20
RING393	21.10	0.28	23.86	0.30	99.00	23.90	99.00	23.90	23.57	0.27	22.44	0.33
RING394	19.50	0.05	23.41	0.22	23.88	0.20	22.39	0.06	21.51	0.05	21.59	0.24
RING395	99.00	23.20	99.00	23.50	24.00	0.24	23.96	0.42	22.79	0.21	21.88	0.45
RING396	20.35	0.09	23.86	0.30	24.00	0.22	23.73	0.18	22.66	0.12	22.72	0.60
RING397	22.13	0.50	24.21	0.70	24.05	0.26	23.47	0.25	22.78	0.23	99.00	22.20
RING398	19.71	0.07	23.29	0.32	24.90	0.52	23.03	0.17	22.87	0.25	21.66	0.26
RING399	20.27	0.10	25.43	1.44	24.36	0.32	23.84	0.34	22.77	0.19	23.36	1.05
RING400	19.07	0.03	99.00	23.50	23.00	0.10	22.05	0.06	21.02	0.04	20.48	0.09
RING401	19.86	0.07	22.81	0.25	22.32	0.05	21.98	0.06	21.33	0.06	20.56	0.10
RING402	21.57	0.25	23.58	0.26	23.83	0.17	23.77	0.23	22.72	0.14	22.48	0.43
RING403	20.68	0.13	22.52	0.11	21.41	0.03	20.98	0.02	20.72	0.02	20.65	0.08
RING404	20.26	0.09	22.49	0.10	22.60	0.07	22.20	0.08	21.70	0.07	20.97	0.12
RING405	20.82	0.11	99.00	23.50	23.99	0.16	23.12	0.12	23.23	0.20	99.00	22.20
RING406	22.24	0.61	23.40	0.22	23.73	0.18	23.35	0.21	22.21	0.11	22.47	0.46
RING407	19.36	0.04	23.28	0.24	22.46	0.06	21.65	0.04	20.83	0.03	20.42	0.11
RING408	21.14	0.22	24.49	0.90	23.62	0.18	24.66	0.73	22.14	0.13	21.49	0.31
RING409	21.58	0.25	23.00	0.14	22.86	0.08	22.24	0.05	22.05	0.08	21.25	0.13
RING410	20.67	0.14	24.02	0.59	23.24	0.13	22.73	0.13	22.68	0.21	99.00	22.20
RING410	22.07	0.28	25.24	0.97	24.78	0.28	25.36	0.76	23.25	0.19	99.00	22.20
RING411	19.70	0.05	99.00	23.50	24.34	0.35	23.54	0.26	21.56	0.08	20.49	0.12
RING412	20.24	0.10	24.77	0.91	23.78	0.19	22.66	0.08	22.54	0.13	21.71	0.23
RING413	20.06	0.08	23.76	0.36	23.87	0.19	22.85	0.10	22.20	0.11	21.17	0.21
RING413	19.64	0.06	23.80	0.39	23.37	0.13	22.57	0.08	21.62	0.07	21.03	0.20
RING414	22.16	0.60	23.19	0.22	24.48	0.35	24.44	0.45	23.90	0.56	22.61	0.84
RING415	21.30	0.26	99.00	23.50	23.29	0.12	22.81	0.10	22.60	0.17	22.07	0.51
RING416	19.27	0.03	23.39	0.26	23.19	0.11	22.14	0.06	21.21	0.05	20.70	0.11
RING417	19.87	0.06	99.00	23.50	23.77	0.20	24.10	0.40	22.21	0.12	20.94	0.19
RING418	21.37	0.20	23.58	0.29	24.33	0.23	24.82	0.54	23.88	0.38	99.00	22.20
RING419	20.42	0.13	23.34	0.25	23.47	0.14	23.22	0.14	21.99	0.07	20.85	0.12
RING420	20.72	0.13	23.96	0.35	23.62	0.16	23.14	0.11	22.32	0.10	21.84	0.27
RING421	20.53	0.13	99.00	23.50	25.37	0.73	24.58	0.39	24.22	0.51	22.51	0.46
RING422	20.43	0.10	23.29	0.20	23.62	0.16	22.37	0.09	21.59	0.06	21.24	0.15
RING423	17.37	0.01	22.19	0.09	20.67	0.01	19.38	0.01	18.80	0.01	18.46	0.01
RING424	21.74	0.36	25.05	1.20	22.64	0.07	22.14	0.06	21.91	0.09	21.30	0.19
RING425	19.44	0.05	23.28	0.24	23.58	0.16	22.00	0.05	21.22	0.05	20.85	0.12
RING426	21.55	0.35	99.00	23.50	23.33	0.16	22.68	0.13	22.80	0.21	99.00	22.20
RING427	21.05	0.20	23.46	0.34	24.21	0.35	22.88	0.15	22.26	0.13	22.56	0.68

RING428	19.89	0.09	23.84	0.49	23.41	0.17	22.97	0.16	21.97	0.10	22.16	0.47
RING429	20.52	0.11	24.44	0.58	23.77	0.19	22.54	0.10	21.82	0.08	21.46	0.18
RING430	19.19	0.03	24.87	0.86	23.75	0.18	21.99	0.06	20.77	0.03	20.37	0.07
RING431	21.69	0.55	25.16	1.33	24.81	0.48	23.79	0.27	24.14	0.71	22.29	0.46
RING432	21.85	0.33	23.72	0.35	23.61	0.16	23.69	0.24	22.46	0.14	21.68	0.30
RING433	20.35	0.09	23.86	0.30	24.00	0.22	23.73	0.18	22.66	0.12	22.72	0.60
RING434	21.20	0.18	24.39	0.50	23.63	0.16	23.91	0.23	23.36	0.25	22.62	0.56
RING435	19.84	0.06	24.22	0.46	23.15	0.11	22.48	0.07	21.75	0.07	20.83	0.15
RING436	20.71	0.14	23.28	0.20	23.18	0.11	22.86	0.14	22.09	0.10	21.86	0.26
RING437	21.02	0.17	22.59	0.16	21.99	0.04	21.41	0.04	21.18	0.05	20.91	0.18
RING438	20.71	0.14	23.28	0.20	23.18	0.11	22.86	0.14	22.09	0.10	21.86	0.26
RING439	21.45	0.26	22.81	0.13	23.57	0.15	23.50	0.25	22.50	0.15	22.42	0.44
RING440	19.64	0.05	23.34	0.21	23.60	0.16	22.56	0.11	21.78	0.08	21.64	0.22
RING441	19.60	0.05	22.96	0.22	22.82	0.10	21.64	0.05	21.07	0.04	20.66	0.12
RING443	20.09	0.07	24.77	1.16	23.43	0.15	23.06	0.17	22.57	0.19	21.21	0.24
RING444	18.11	0.01	22.24	0.11	21.31	0.02	20.16	0.01	19.63	0.01	19.42	0.05
RING445	20.44	0.13	23.02	0.19	23.82	0.19	23.13	0.14	22.38	0.14	21.37	0.27
RING446	20.24	0.11	99.00	23.50	23.80	0.19	24.19	0.36	22.33	0.13	21.89	0.43
RING447	20.46	0.12	99.00	23.50	99.00	23.90	23.66	0.22	23.06	0.26	21.74	0.36
RING447	20.98	0.19	99.00	23.50	25.51	0.90	23.26	0.15	23.47	0.37	22.28	0.49
RING448	22.00	0.41	23.15	0.26	23.46	0.16	22.68	0.12	22.42	0.16	21.62	0.35
RING449	20.88	0.15	24.07	0.67	23.83	0.21	23.16	0.17	22.90	0.23	21.51	0.32
RING450	18.49	0.02	99.00	23.50	22.63	0.07	20.95	0.02	20.13	0.02	19.68	0.06
RING451	17.37	0.01	22.19	0.09	20.67	0.01	19.38	0.01	18.80	0.01	18.46	0.01
RING452	20.07	0.07	23.09	0.24	22.90	0.11	22.68	0.13	22.39	0.15	21.61	0.28
RING453	19.76	0.05	23.76	0.45	24.03	0.30	24.85	0.91	22.27	0.13	21.99	0.40
RING454	21.60	0.31	23.28	0.32	23.75	0.19	22.71	0.11	22.88	0.22	22.71	0.96
RING455	21.90	0.40	23.09	0.27	23.60	0.17	22.81	0.12	22.49	0.15	99.00	22.20
RING456	19.42	0.04	23.35	0.25	23.51	0.16	22.11	0.06	21.05	0.04	20.92	0.15
RING457	20.88	0.16	23.55	0.25	23.50	0.14	23.00	0.16	23.47	0.35	22.77	0.61
RING458	20.76	0.15	23.57	0.26	24.36	0.32	23.45	0.24	23.58	0.39	22.17	0.35
RING460	21.88	0.41	23.67	0.30	23.92	0.21	23.09	0.10	22.75	0.14	99.00	22.20
RING461	21.37	0.27	25.06	0.92	23.54	0.15	22.46	0.06	21.91	0.07	23.11	0.92
RING462	19.80	0.07	23.71	0.44	22.25	0.05	21.21	0.03	20.93	0.04	20.28	0.10
RING463	18.15	0.02	22.65	0.16	21.04	0.02	19.78	0.01	19.31	0.01	19.00	0.03
RING464	20.53	0.14	99.00	23.50	23.41	0.13	22.84	0.09	22.37	0.10	21.61	0.17
RING465	21.45	0.31	22.80	0.17	22.14	0.04	21.57	0.04	21.79	0.09	22.37	0.66
RING466	20.84	0.17	22.99	0.25	23.13	0.11	22.46	0.09	21.84	0.09	21.56	0.33
RING467	19.52	0.05	99.00	23.50	23.20	0.11	22.22	0.05	21.47	0.04	21.76	0.25
RING468	20.61	0.17	23.26	0.26	22.33	0.05	21.73	0.04	21.22	0.05	21.01	0.19
RING469	21.34	0.28	22.15	0.09	22.01	0.04	21.74	0.04	20.59	0.03	21.59	0.32
RING470	20.11	0.07	24.22	0.58	24.31	0.30	23.59	0.23	23.25	0.32	22.22	0.39
RING471	19.81	0.06	23.92	0.58	23.19	0.12	23.32	0.20	21.80	0.08	21.95	0.48
RING472	20.86	0.17	99.00	23.50	23.45	0.15	23.11	0.16	22.52	0.16	21.06	0.21
RING473	20.15	0.10	23.40	0.30	23.50	0.14	22.34	0.07	21.65	0.07	22.53	0.76
RING474	99.00	23.20	23.18	0.19	23.59	0.16	24.49	0.46	22.34	0.10	21.97	0.33
RING475	21.42	0.44	22.86	0.20	23.73	0.20	22.78	0.13	22.02	0.12	21.21	0.24
RING476	18.92	0.02	23.62	0.34	22.16	0.04	21.01	0.02	20.55	0.03	20.31	0.07
RING477	20.63	0.12	22.74	0.15	23.89	0.21	22.83	0.12	22.49	0.16	99.00	22.20

RING478	20.40	0.08	25.12	1.34	22.56	0.06	21.77	0.04	21.35	0.06	20.93	0.12
RING479	20.86	0.14	99.00	23.50	24.24	0.36	99.00	23.90	22.67	0.14	22.08	0.38
RING480	21.17	0.17	22.74	0.12	22.92	0.08	22.72	0.08	23.00	0.18	23.61	1.19
RING480	99.00	23.20	25.09	0.62	24.35	0.20	25.15	0.46	24.13	0.31	23.80	0.85
RING481	21.40	0.24	25.37	1.34	24.49	0.36	25.02	0.64	22.86	0.16	23.30	1.01
RING482	99.00	23.20	99.00	23.50	25.90	1.30	24.11	0.40	23.95	0.59	21.23	0.19
RING483	21.52	0.30	22.58	0.17	22.44	0.06	21.81	0.05	21.66	0.08	21.13	0.24
RING484	21.44	0.26	99.00	23.50	24.60	0.39	23.30	0.20	22.95	0.27	99.00	22.20
RING485	20.55	0.11	24.73	1.12	23.59	0.20	22.46	0.09	22.28	0.15	21.75	0.32
RING486	21.19	0.19	99.00	23.50	99.00	23.90	22.66	0.11	24.00	0.73	22.10	0.45
RING487	23.06	0.32	26.10	1.18	24.91	0.20	25.55	0.47	24.14	0.25	22.57	0.20
RING488	22.08	0.48	22.47	0.14	25.43	1.07	23.18	0.18	22.45	0.18	22.19	0.48
RING489	19.53	0.06	22.42	0.13	22.66	0.09	21.47	0.04	20.91	0.04	20.75	0.13
RING490	20.62	0.17	99.00	23.50	25.60	1.25	23.79	0.31	22.42	0.17	99.00	22.20
RING491	20.16	0.10	24.95	1.16	23.86	0.20	22.87	0.13	21.93	0.09	21.46	0.24
RING492	20.99	0.20	24.40	0.74	99.00	23.90	24.07	0.33	23.83	0.55	21.64	0.33
RING493	21.74	0.32	99.00	23.50	23.48	0.17	22.85	0.15	23.84	0.52	99.00	22.20
RING494	20.30	0.12	22.75	0.16	22.70	0.07	21.83	0.04	21.41	0.06	20.77	0.15
RING495	20.52	0.11	23.82	0.49	23.89	0.25	23.58	0.30	23.49	0.38	22.17	0.54
RING496	19.97	0.07	21.79	0.08	21.04	0.02	20.51	0.02	20.33	0.02	20.60	0.13
RING497	21.64	0.39	23.67	0.46	23.43	0.14	23.11	0.17	22.66	0.20	99.00	22.20
RING498	18.77	0.03	22.86	0.22	22.10	0.04	20.58	0.02	20.15	0.02	19.74	0.07
RING499	20.04	0.09	23.86	0.33	23.62	0.16	22.95	0.11	22.65	0.13	21.90	0.27
RING500	20.84	0.17	22.98	0.20	24.44	0.34	23.25	0.16	22.84	0.22	21.86	0.41
RING501	19.48	0.06	99.00	23.50	24.00	0.23	23.48	0.19	21.77	0.08	21.43	0.27
RING502	20.93	0.22	22.42	0.12	22.10	0.04	21.60	0.04	21.34	0.06	21.04	0.19
RING503	20.70	0.14	99.00	23.50	24.88	0.51	23.38	0.21	22.20	0.13	21.70	0.41
RING504	21.04	0.15	23.02	0.23	24.07	0.30	23.35	0.21	22.91	0.27	21.12	0.18
RING505	20.94	0.19	99.00	23.50	22.63	0.07	22.15	0.07	21.56	0.07	21.33	0.21
RING506	20.32	0.09	99.00	23.50	23.84	0.20	22.92	0.14	21.85	0.09	21.54	0.25
RING507	19.05	0.05	22.93	0.18	22.72	0.07	21.40	0.03	20.77	0.03	20.41	0.07
RING508	20.89	0.32	99.00	23.50	23.75	0.18	23.25	0.17	22.34	0.14	22.10	0.35
RING509	20.29	0.08	24.75	0.91	23.33	0.14	22.52	0.09	22.15	0.10	21.70	0.31
RING510	18.94	0.02	24.09	0.62	22.55	0.08	20.99	0.03	20.52	0.03	20.13	0.07
RING511	22.17	0.43	23.16	0.27	24.58	0.49	23.50	0.24	22.73	0.23	21.96	0.39
RING512	20.14	0.06	99.00	23.50	24.67	0.53	24.00	0.38	22.25	0.15	23.36	1.42
RING513	20.13	0.07	22.30	0.12	22.04	0.05	21.24	0.03	20.91	0.04	20.48	0.10
RING514	19.67	0.05	23.30	0.25	23.72	0.18	22.53	0.10	21.72	0.08	20.97	0.15
RING515	18.89	0.03	23.09	0.21	22.64	0.07	21.10	0.03	20.46	0.02	20.11	0.07
RING516	20.54	0.12	24.17	0.67	23.92	0.26	23.25	0.22	22.45	0.14	22.30	0.61
RING517	20.26	0.07	99.00	23.50	24.40	0.24	24.04	0.18	22.64	0.10	23.38	0.81
RING518	17.92	0.01	21.93	0.08	20.59	0.01	19.65	0.01	19.16	0.01	18.99	0.03
RING519	18.94	0.02	24.09	0.62	22.55	0.08	20.99	0.03	20.52	0.03	20.13	0.07
RING520	18.24	0.01	99.00	23.50	21.76	0.04	20.28	0.01	19.68	0.01	19.48	0.04
RING521	21.32	0.18	99.00	23.50	24.74	0.28	24.14	0.22	23.58	0.27	99.00	22.20
RING522	19.25	0.04	24.64	0.52	23.09	0.10	22.28	0.05	21.25	0.03	20.49	0.06
RING523	99.00	23.20	23.54	0.32	24.95	0.54	23.18	0.17	23.40	0.36	99.00	22.20
RING524	20.03	0.07	24.61	1.02	23.76	0.23	23.37	0.24	21.92	0.09	21.16	0.21
RING525	20.61	0.11	22.49	0.14	22.02	0.05	21.26	0.03	21.03	0.05	20.55	0.11

RING526	21.13	0.21	24.27	0.44	23.45	0.14	23.26	0.12	22.12	0.09	99.00	22.20
RING527	21.14	0.23	24.87	1.40	23.09	0.10	22.67	0.11	22.93	0.26	21.93	0.50
RING528	20.28	0.10	99.00	23.50	23.84	0.20	23.22	0.18	23.15	0.32	22.78	1.10
RING529	20.19	0.09	24.76	0.65	23.12	0.10	22.43	0.06	21.73	0.06	21.10	0.13
RING530	21.29	0.21	24.04	0.59	23.52	0.19	22.42	0.09	21.87	0.10	21.68	0.30
RING531	99.00	23.20	99.00	23.50	25.03	0.74	99.00	23.90	23.20	0.35	22.75	0.81
RING532	19.71	0.09	99.00	23.50	23.22	0.11	22.04	0.05	21.06	0.04	21.16	0.14
RING533	19.95	0.07	23.95	0.37	24.01	0.23	23.04	0.12	21.87	0.09	21.36	0.17
RING534	19.83	0.07	23.51	0.40	23.35	0.13	22.58	0.10	21.67	0.08	21.27	0.27
RING535	22.33	0.66	22.88	0.22	23.00	0.09	22.89	0.14	22.95	0.27	99.00	22.20
RING536	20.01	0.05	24.42	0.48	23.62	0.16	22.97	0.09	22.09	0.07	21.33	0.15
RING537	19.65	0.04	99.00	23.50	23.52	0.15	22.09	0.06	21.22	0.05	20.60	0.12
RING538	19.11	0.03	22.09	0.08	21.93	0.04	20.76	0.02	20.38	0.02	20.12	0.08
RING539	19.67	0.05	23.30	0.25	23.72	0.18	22.53	0.10	21.72	0.08	20.97	0.15
RING540	19.83	0.07	23.51	0.40	23.35	0.13	22.58	0.10	21.67	0.08	21.27	0.27
RING541	19.39	0.03	23.66	0.21	23.55	0.15	22.43	0.06	21.32	0.03	20.89	0.08
RING542	19.93	0.05	99.00	23.50	24.01	0.28	23.04	0.14	22.27	0.09	23.09	1.07
RING543	19.11	0.03	22.09	0.08	21.93	0.04	20.76	0.02	20.38	0.02	20.12	0.08
RING544	20.15	0.10	24.01	0.44	23.53	0.15	22.37	0.08	21.59	0.07	22.21	0.52
RING545	21.71	0.62	99.00	23.50	24.39	0.32	23.25	0.17	23.48	0.38	21.86	0.37
RING546	18.99	0.03	23.13	0.23	22.71	0.07	21.51	0.04	20.70	0.03	20.35	0.09
RING547	19.96	0.07	23.78	0.41	23.16	0.10	22.94	0.12	24.04	0.61	99.00	22.20
RING548	19.61	0.05	23.35	0.32	22.70	0.09	21.77	0.06	21.02	0.04	20.94	0.17
RING549	20.77	0.13	24.47	0.61	23.12	0.11	22.50	0.07	20.94	0.03	21.87	0.24
RING550	20.73	0.13	99.00	23.50	99.00	23.90	99.00	23.90	99.00	23.00	21.70	0.31
RING551	21.12	0.23	23.07	0.19	23.84	0.20	23.35	0.20	23.51	0.40	22.24	0.53
RING552	21.73	0.58	23.45	0.31	23.73	0.18	24.24	0.41	23.05	0.26	99.00	22.20
RING553	19.46	0.07	23.09	0.22	23.55	0.15	22.53	0.08	21.98	0.09	20.80	0.13
RING554	20.82	0.13	22.68	0.16	23.10	0.12	23.14	0.20	22.17	0.12	21.60	0.26
RING555	19.70	0.05	24.30	0.52	24.47	0.35	23.48	0.18	21.81	0.07	20.86	0.10
RING556	20.57	0.10	99.00	23.50	24.06	0.24	22.55	0.08	22.07	0.08	22.59	0.47
RING557	20.97	0.18	23.07	0.27	22.87	0.08	21.97	0.06	21.40	0.06	21.34	0.29
RING558	19.50	0.09	24.86	1.15	23.08	0.10	21.90	0.05	21.39	0.06	21.92	0.39
RING559	20.65	0.20	23.13	0.23	22.98	0.09	22.70	0.10	21.92	0.09	21.56	0.28
RING560	20.66	0.13	22.65	0.11	21.96	0.04	21.33	0.03	21.31	0.04	20.96	0.11
RING561	20.74	0.13	23.66	0.32	23.12	0.10	23.04	0.15	21.73	0.08	21.35	0.23

Chapter 4: Ring Catalog Analysis

This chapter will present preliminary analysis done on the Ring Galaxy Catalog (Figure 8) presented in Chapter 3 of this paper. The analysis consists of determining where ring galaxies fall into the spectrum of all galaxies, and also comparing the ring galaxies in the past (using the Ring Galaxy Catalog) to the ring galaxies in the nearby universe (using the Arp-Madore Peculiar Galaxy Catalog (1987)).

In the introduction, the concept of number density of galaxies was explained. It is possible to tell the density of ring galaxies by comparing the number of ring galaxies divided by the total number of galaxies for both surveys. However, issues such as shredding and detecting things that are not galaxies make it difficult to compare the total counts from each survey. In order to reconcile the Arp-Madore counts and the COSMOS survey counts, I used my representative sample of the COSMOS data to find a magnitude limit that included 90% of all of the galaxies (*I*-band magnitude $\leq$ 25 mag). I then reran a COSMOS search for photometric data without any spatial constraints (covering all 2 square degrees of the sky) but with an upper magnitude limit of $I = 25$ mag. This upper

magnitude limit is also the magnitude of the dimmest ring galaxy observed in the COSMOS field (note: higher magnitudes mean dimmer sources). Any "galaxies" with magnitudes higher than that would be dimmer than an actual galaxy, and must be a glob of dust or something else. This gave me a total number of galaxies in the COSMOS survey of 289,847, which is still probably an overestimate considering I have searched extensively through the COSMOS catalog searching for ring galaxies and there is an enormous amount of wispy/extragalactic junk that has no relation at all to galaxies. Since I found 561 ring candidates out of 289,847 galaxies, this means that approximately 0.19% of galaxies in the COSMOS field are ring galaxies. Compared with the 0.55% of all galaxies determined to be rings in the nearby universe (using the Arp-Madore catalog, see introduction), it would appear that there were less ring galaxies in the past than there are today. However, considering the simulations done regarding large scale structure throughout time, it is now generally accepted that the rate of mergers has not been constant in the past. Based on the comparison of density of ring galaxies, perhaps $z = 0.959$ was a time with an higher collision rate than we find today.

The problem with measuring the number density of ring galaxies is that the specific morphology of a ring can only be detected to a certain redshift and magnitude. If the galaxy is not bright enough, it is impossible to claim that it is a ring, even though the ring structure may still exist. The magnitude distribution of the ring sample (561 sources) and the representative sample of COSMOS galaxies (6128 sources) can be seen in Figures 9 and 10. The magnitude of the average ring is 22.6, whereas the magnitude of the average galaxy in the representative sample is 24.4. Rings are, on average, much

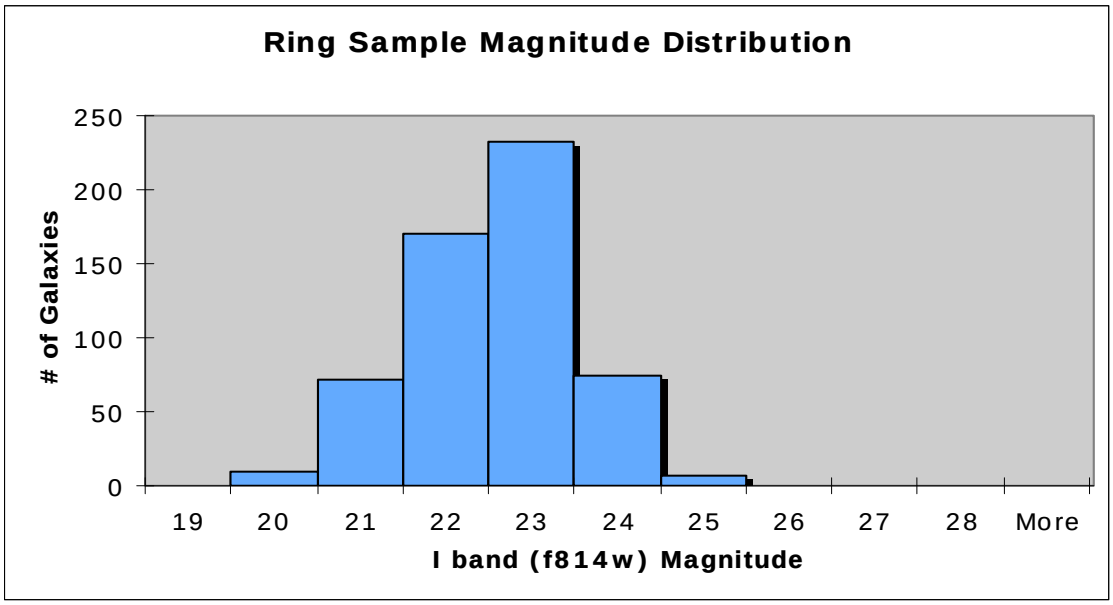

Figure 9: *I*-band magnitude distribution of the COSMOS ring sample

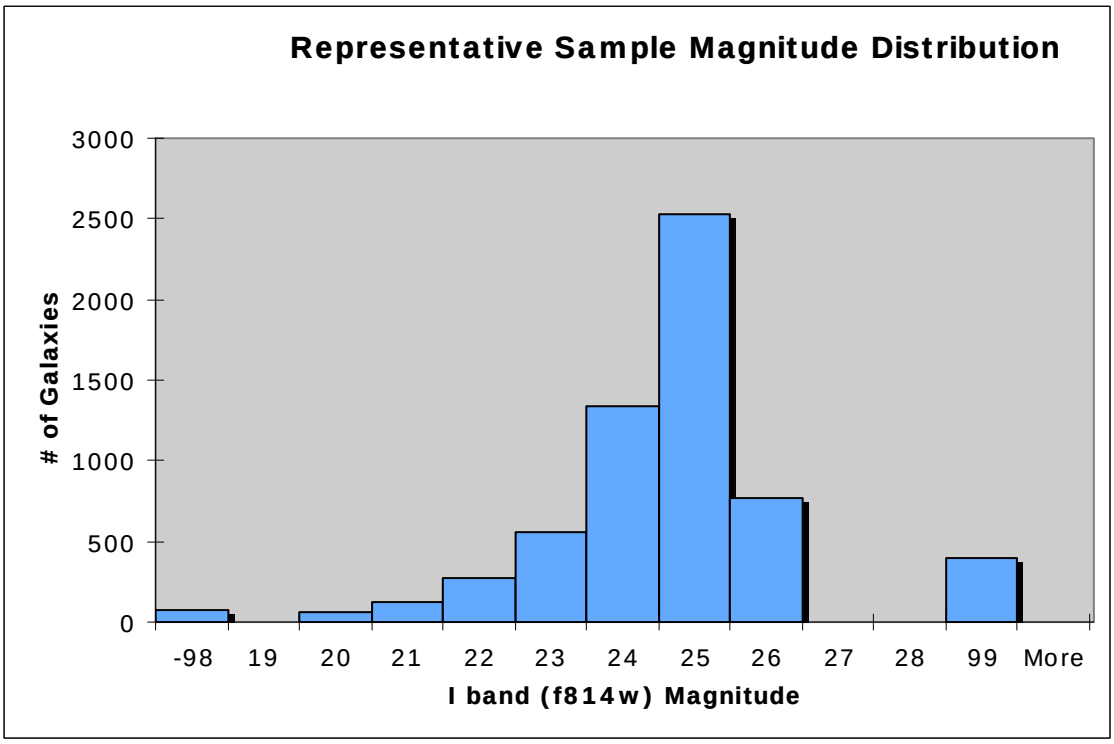

Figure 10: *I*-band magnitude distribution of the COSMOS representative sample

brighter than the general galaxy, perhaps only because they are hard to detect when they are dim. If we compare the bright end of the representative sample with the ring sample,

perhaps we will get a better idea of the number density of rings at a high redshift. Only considering rings and representative galaxies that have an *I*-band magnitude ≤ 23 mag, which is not quite the limiting magnitude for rings, but it is where the ring sample begins to get robust, we get a different population density. 474 rings have an *I*-band magnitude ≤ 23 mag, while 64101 sources were found from the COSMOS Photometry Catalog that have a magnitude ≤ 23. This means, of the brighter galaxies, 0.74% are ring galaxies, which makes much more sense in terms of comparing galaxies at high redshift with galaxies at low redshift. However, it is not entirely possible to compare the Ring Galaxy Catalog (Figure 8) with the Arp-Madore catalog because the magnitude ranges are not comparable. As stated above, we do not know the range of magnitudes in the Arp-Madore catalog because it is not a magnitude-limited sample.

The redshift distribution of both samples can be found in Figures 11 and 12. The redshift distribution is also informative in showing where it is possible to detect ring galaxies. In the representative sample, the redshifts range all the way to z = 3. In the ring sample, it is uncommon to find a ring at a redshift z > 1.6, and there are only two rings at a redshift z > 2. This shows that the change in the number density calculation made above is a reasonable one. The average redshift for a ring is z= 0.96, and the average redshift for a galaxy from the representative sample is z = 0.94, which shows that even though the maximum is very different, the average is similar.

Figures 13 and 14 show the (*g* - *I*) color distribution of both the ring sample and the COSMOS representative sample. The average (*g* - *I*) color of a ring is 1.7 mag, and the average (*g* - *I*) color of a representative galaxy is 0.86 mag, which shows that rings tend to be comparatively brighter in the *g*-band and dimmer in the *I*-band.

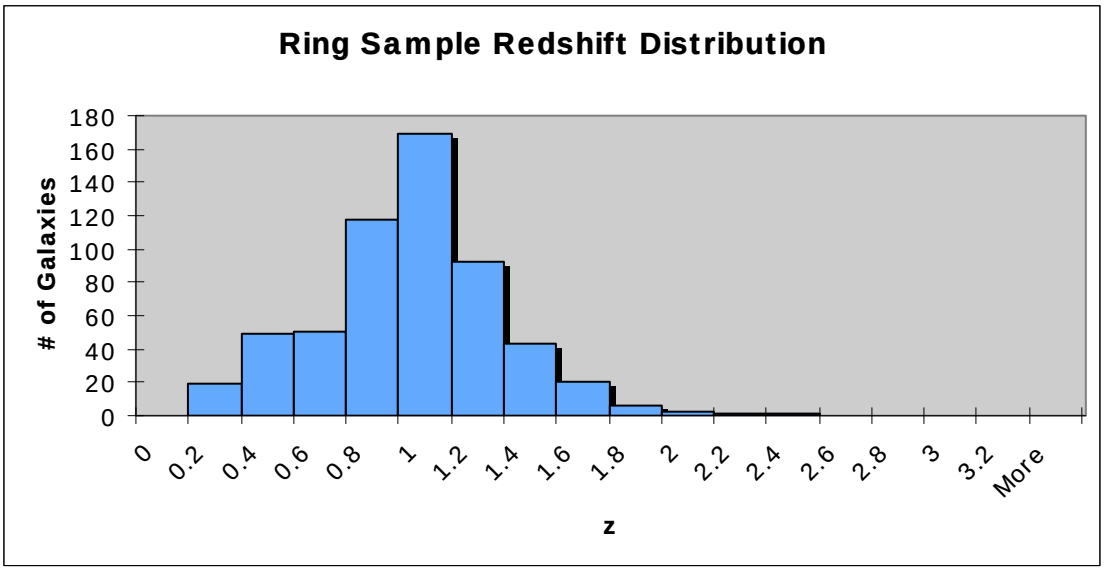

Figure 11: Redshift distribution of rings in the COSMOS field

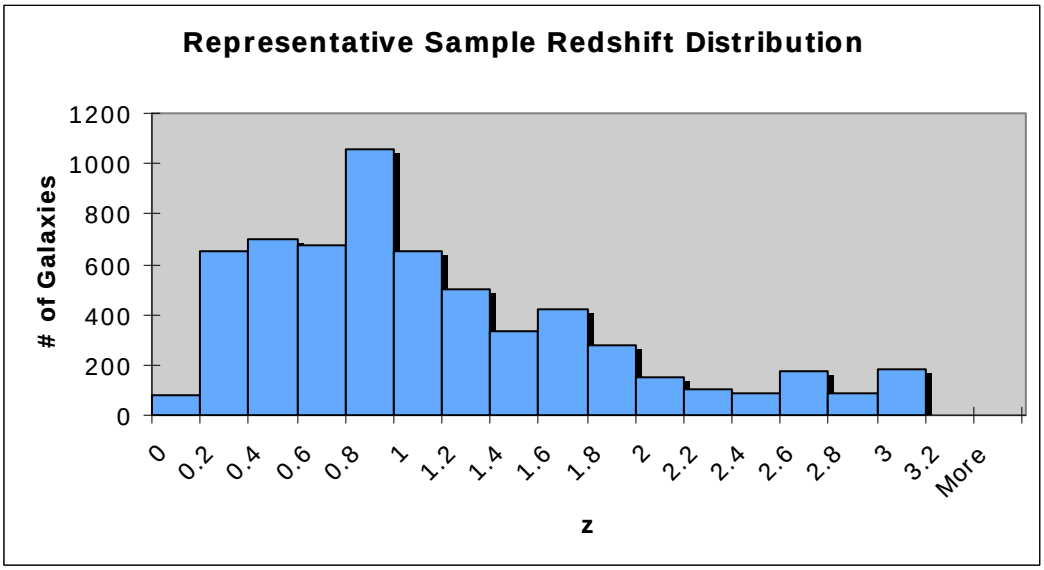

Figure 12: Redshift distribution of the representative sample in the COSMOS field

Figure 15 shows a (*g*-*I*) Color vs. Magnitude Plot. The line at x = 0 is an artifact of undefined magnitudes being listed as 99 mag or -99 mag. In this case, any galaxies that have undefined magnitudes in the *g*-band and the *I*-band will cancel to appear to have a color of 0 mag, which is not an unreasonable color, but simply has no physical significance on the graph. Once again it is obvious that it is only possible to see rings

with low magnitudes (bright rings).

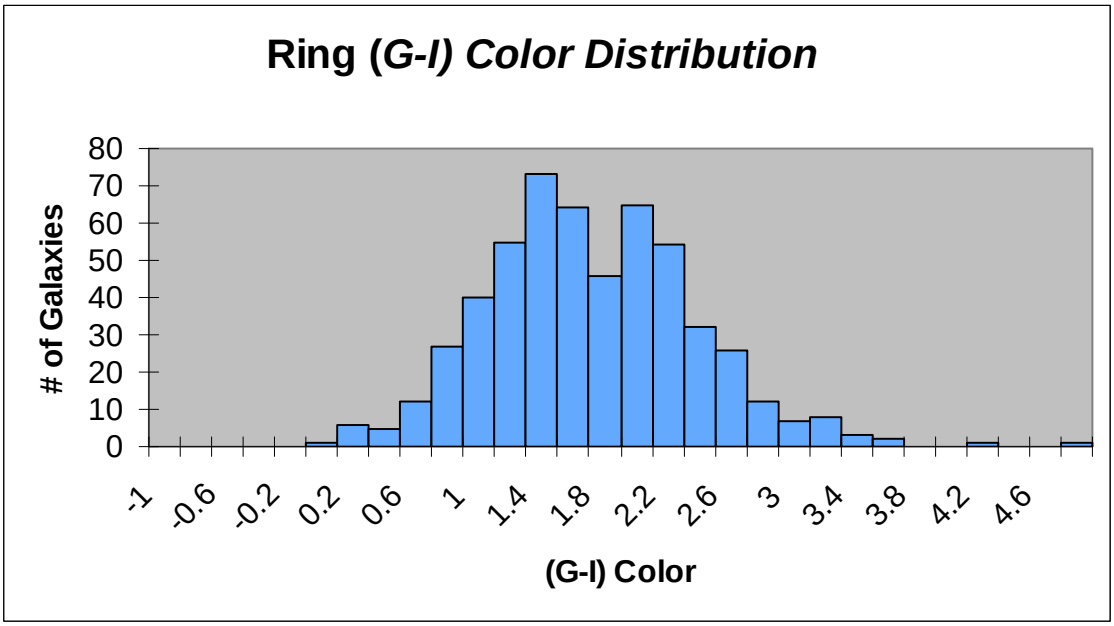

Figure 13: (*G-I*) Color distribution of ring galaxies in the COSMOS field

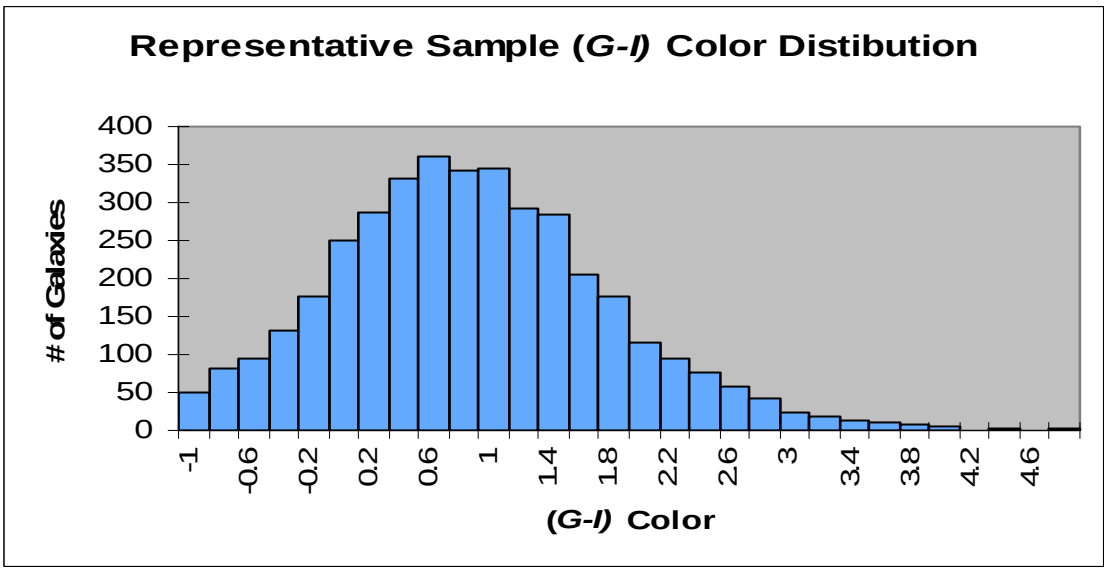

Figure 14: (*G-I*) Color distribution of representative galaxies in the COSMOS field

Another way to calculate the difference between the density of local rings and far away rings is to determine the volume density of the ring galaxies at both areas of space. Out of 89 rings in the Arp Madore catalog with a measured recessional velocity, we find

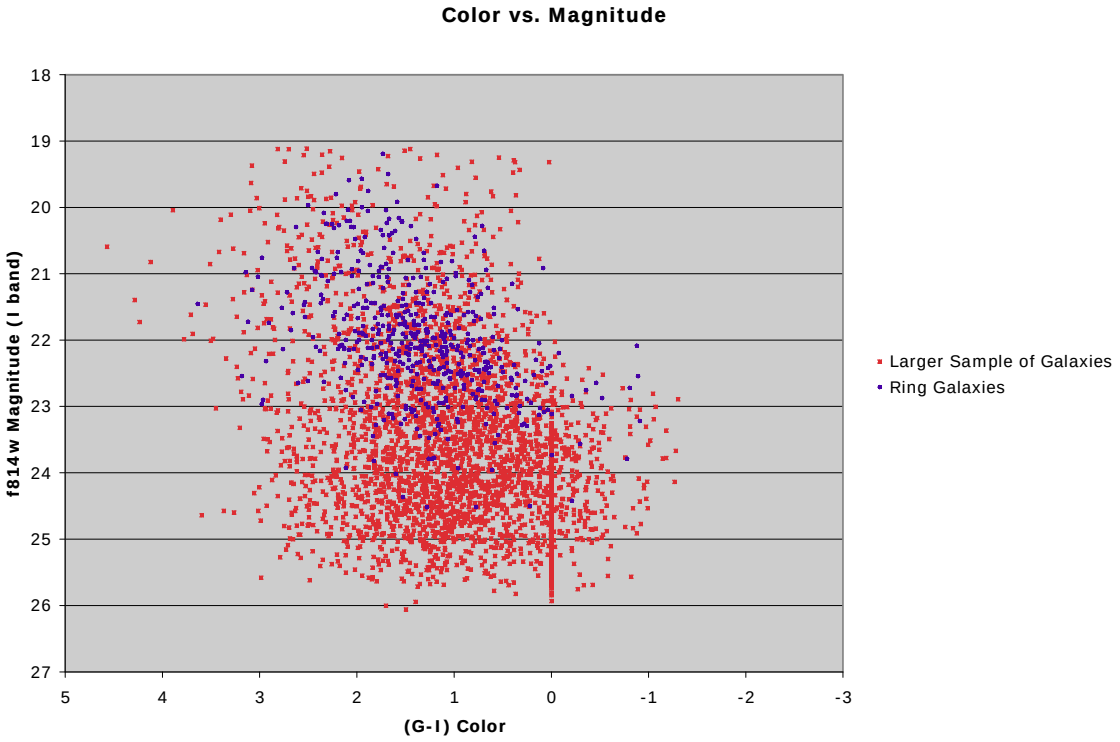

Figure 15: A (*G-I)* Color vs. Magnitude Plot of both the COSMOS ring sample and the larger representative sample. The line at x = 0 is an artifact of undefined color.

an average velocity of 11498 km/s and a maximum velocity of 26443 km/s. This converts (using a Hubble constant value of $H_0 = 75 \frac{km/s}{Mpc}$) to an average distance of 153.3 Mpc and a maximum distance of 352.6 Mpc. I will use the average distance in order to determine the volume of the sphere around earth which was searched to determine ring galaxies in the Arp-Madore Catalog. This sphere has a volume of 1.51 x 10^7 Mpc. Arp and Madore found 552 rings in this volume, which corresponds to a volume density of 3.66 x10^{-5} rings/Mpc. The high redshift sample volume density must be calculated differently, because the COSMOS field is not a sphere around the earth, but instead, the volume of the COSMOS field can be represented by a box, 2 degrees on each side. Since

we know the average redshift of the rings in the COSMOS field (average z = 0.96), we can find a scale using NED that converts arcminutes to kpc (at z = 0.96, scale = 7.624 kpc/arcminute). Assuming that this scale holds true for the entire "box" field of view, the length of each 2 degree side converts to 5.49×10^4 kpc, which equals 54.9 Mpc. This creates a volume of 1.65×10^5 Mpc^3. I discovered 561 ring galaxies in this 1.65×10^5 Mpc^3 box, which corresponds to a volume density of 3.39×10^{-3} rings/Mpc, approximately 2 orders of magnitude greater than the volume density found using the nearby sample.

The volume density calculation and the brightness-corrected number density calculation both state that there are more ring galaxies at high redshifts than in the local universe. This makes sense considering that it is widely accepted that the galaxy is much larger today than it was in the past, and also that ring galaxies are formed through collisions. This must mean that there were more collisions in the past than there are currently. This hypothesis could be tested further by examining other peculiar galaxies that have most likely been caused by a collision at varying redshifts. Perhaps only rings are more common in the past, though this is unlikely.

Chapter 5: Conclusion

This paper examined a few different types of interacting galaxies and the implications the data has on cosmological theories. An analysis of the Holmberg Effect, Holmberg (1969)'s observation that companion galaxies tend to be near the poles of edge-on galaxies rather than in the planes, was done by reexamining the spirals viewed by Holmberg. Only using radial velocity confirmed companions to test for this effect showed that if anything, the opposite of the Holmberg effect is true (see Figure 6). However, due to small number statistics, more edge-on spirals and their companions would have to be viewed in order to determine if this is an actual physical effect of anisotropic companion distribution around primary galaxies. It is important to discover if there is a preferred distribution, because it could point to the distribution of dark matter around the primary galaxies, and have interesting impacts on large-scale universal structure and cosmology theory.

Chapter 3 is a detailed explanation of the formation of the Ring Galaxy Catalog (Figure 8), which was created to increase the number of ring galaxies available to study.

These galaxies are created through collision events, so many interesting questions could be studied using this catalog. In Madore, Nelson, and Petrillo (2008), the authors searched for visible companions to ring galaxies in the Arp-Madore Catalog of Southern Peculiar Galaxies. The idea was that any galaxies without visible companions must be formed through a collision with non-luminous galaxies. This search led to no convincing examples of a ring galaxy without a visible companion, but searching for ring companions in the Ring Galaxy Catalog will further illuminate this issue. If there are several rings without visible companions, then perhaps the "missing satellite" concept can be solved by concluding that the missing galaxies are simply non-luminous, but this is beyond the scope of this paper.

Analysis of the ring galaxies from the catalog presented in Chapter 3 compared to a representative sample of the field which I searched through to find them led to knowledge of where ring galaxies fit into the scheme of all galaxies. Figures (9-15) present distribution findings and scatter plots that suggest that rings tend to be bright galaxies. This may simply be because it is difficult to see morphology in dim galaxies. Considering this fact, the number density calculation was made only for bright galaxies. It was found that 0.74% of all bright galaxies in the COSMOS field are ring galaxies. For the Arp-Madore Catalog of nearby galaxies, it was found that 0.55% of all galaxies are ring galaxies. No brightness modification was made for the Arp-Madore sample, and in fact, the magnitudes of the Arp-Madore rings are unknown, so it is difficult to compare these two percents at all.

The other way to measure density is using volume density, and the Ring Analysis Chapter goes into details on how this was done. The density of rings in the nearby

universe, using the Arp-Madore data, is 3.66 x10^{-5} rings/Mpc. The density of rings in past, at high redshift using the COSMOS data, is 3.39 x 10^{-3} rings/Mpc. This 2 order of magnitude difference shows that rings were much more common in the past. This can be attributed to the number of collisions being larger in past, which confirms the cosmological theory that galaxies were closer together in the past, since the universe was smaller.

In order to expand upon these results, further research could include a more detailed analysis of the Holmberg Effect, using his edge-on galaxies and others. This will be more productive as NED (NASA/IPAC Extragalactic Database) expands the amount of galaxies with known redshifts. The Ring Galaxy Catalog could be examined in many ways, including searching for visible companions and coming up with classification schemes for the rings. Table 4 will also be very useful for further research since it includes several interesting pieces of data that I simply could not go into detail about in this paper. Examining the masses, e(B-V) (an extinction factor independent of redshift), and the absolute *V*-band magnitudes of the rings compared to the full or a representative COSMOS sample would be very informative, as would comparing the different filter magnitudes of the ring galaxies.

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